भारतीय विज्ञान संस्थान

Scheme of Instructions

August-December 2026 Semester

Preface

The Scheme of Instruction (SoI) and Student Information Handbook (Handbook) contain the courses and rules and regulations related to student life in the Indian Institute of Science. The courses listed in the SoI and the rules in the Handbook are primarily meant for post- graduate students of the Institute. Undergraduate students are allowed to credit or audit the courses listed in the SoI with the consent of the instructors.

The course listings are in conformance with the Divisional structure of the Institute, with the courses of each department of a Division listed in a separate subsection. For instance, all courses of the Aerospace Engineering department have the prefix AE, and are listed in the Aerospace Engineering subsection within the Mechanical Sciences Division. The only exception to this pattern is the Electrical Sciences Division, where the courses are organized under the sub-sections E0 through E9, according to the areas to which they belong. For instance, all Computer Science and Automation courses of the Electrical Sciences Division have the prefix E0, and are found in the corresponding sub- section, although the instructors come from all four departments of the division. The course codes are given in the Table of Contents.

The listing of each course consists of the course number, the title, the number of credits and the semester. The course number indicates both the department and the level of the course. For instance, MA 205 indicates that the course is offered by the Mathematics department and is at the 200 level. Such 200 level courses are either basic or second level graduate courses. The 300 level courses are advanced courses primarily meant for research scholars, but can also be taken by course students who have the appropriate background; these courses can be taken only with the consent of the instructors. Most courses are offered only once a year, either in the August or in the January semester. Very few selected courses are offered in the summer term.

The number of credits is given in the form M:N, where M indicates the number of lecture credits and N the number of laboratory credits. Each lecture credit corresponds to one lecture hour per week, while each laboratory credit corresponds to a 3-hour laboratory class. Thus, a course with 2:1 credits indicates that it has 2 lecture hours and one 3-hour laboratory session each week, while a course with 3:0 credits indicates a course with 3 lecture hours and no laboratory session.

The Institute offers research-based doctoral programmes and Master's programmes that are both course-based and research-based. Each course- based Master's programme consists of core courses, electives and a dissertation project. Details of the requirements can be found under the course listing of the departments or divisions that offer them. Student are assigned faculty advisors who will advise them in selecting and dropping courses, and monitor progress through the academic program. In order to register for a course, each student needs the approval of both the faculty advisor and the course instructor. The number and type of courses taken in the first and subsequent semesters depend on the programme and department the student is registered in – the faculty advisor and the Department Curriculum Committee (DCC) will guide the students on the core and elective courses they should register for. Students are permitted to claim an exemption from core courses on the basis of having taken them earlier. Details of how to claim such an exemption are given in the Student Information Handbook.

The Institute follows a grading system, with continuous assessment. The course instructor first aggregates the individual marks of each student from the class tests, assignments and final examination scores. These marks are then mapped to letter grades, and only the grade is announced. The point values of grades are as follows: A +:10, A: 9, B+: 8, B: 7, C:6, D:5, F: 0. The grades A+ through D are passing grades, and F is a failing grade.

All the course-based programmes have a specified set of core courses. The doctoral and research-based Master's programmes may have specific core courses, which depend on the division and department. Students in research programmes have to take a minimum number of credits as part of their Research Training Program (RTP). For PhD students in Science, the RTP consists of a minimum of 12 credits. For PhD students in Engineering who join with a Master's degree, the RTP requirement is a minimum of 12 credits. For PhD students in Engineering who join with a Bachelor's degree, the RTP consists of a minimum of 24 credits. Similar RTP requirements apply for students who upgrade or continue their registration from the Masters programmes of the Institute. For the research-based Master's degree, the RTP consists of minimum 12 credits. The Integrated PhD programme has 64 credits. Research students have the option of crediting courses beyond the RTP requirement as detailed in the Student Information Handbook.

Detailed information with regard to the regulations of the various programmes and the operation of different aspects of Institute activities are given in the Student Information Handbook. Students are urged to read this material carefully, so that they are adequately informed.

Chair
Senate Curriculum Committee

Division of Medical Sciences

ISAAC Centre for Public Health

PU 201 (AUG) 3 : 0

Principles and Practice of Public Health

Foundational principles of public health, History of public health in the global and Indian context, Determinants of public health (biological, genetic, social, cultural, behavioural and commercial), Burden of diseases globally and in India, Infectious disease dynamics and infectious diseases of public health importance in terms of burden, risk factors and interventions, Principles of disease screening, Burden and surveillance of leading risk factors for noncommunicable diseases and the noncommunicable diseases of public health importance in terms of burden and interventions, Fundamentals of reproductive, maternal, child and adolescent health, Public health nutrition, Principles of public health ethics, Emerging challenges in Public Health

Prabhdeep Kaur

Pre-requistes :
None

References : Detels, Roger, and others (eds), Oxford Textbook of Global Public Health, 6 edn (Oxford, 2015; online edn, Oxford Academic, 1 Feb. 2

Boulton, M. L., & Wallace, R. H. (Eds.). (2021). Maxcy-Rosenau-Last Public Health & Preventive Medicine (16?h ed.). McGraw-Hill.

PU 204 (AUG) 3 : 1

Health systems

Lecture: This course covers an introduction to health systems and the evolution of health system, along with the building blocks of health system such as health system governance and leadership, health system financing, health workforce, digital technologies, and medical products, vaccines, and technology. It also includes Quality concepts, national health programs, global health systems, and health system regulation. The course emphasises health equity, quality improvement, and patient centered care. Laboratory/practical: Will involve activities such as Health system mapping – Urban PHC/private clinic/hospital/ Namma clinic; Understanding building blocks through national health program/running private hospital/ interviews with program manager/DD; reform package for a hypothetical country; Interactions with ASHA/ANM/ MO/THO/ case studies; NQAS assessment exercise at PHC/AAM; QI protocol workshop: build a complete protocol; Debate on the Guidance on Ethics & Governance of Artificial Intelligence for Public Health.

Archana Siddaiah , Arjun M C

Pre-requistes :
None

References : 1. World Health Organization (2007). Everybody's Business: Strengthening Health Systems to Improve Health Outcomes – WHO's Framework for Action [online] Geneva: WHO.

PU 202 (AUG) 3 : 1

Epidemiology

Overview
Epidemiology is central to public health research and practice. This course will introduce students to the foundational principles of measuring disease frequency, association, and causation in human populations. It will cover key epidemiologic study designs, including cross-sectional, case-control, cohort, and interventional approaches, focusing on their assumptions, strengths, and limitations. Students will learn about random error, bias, confounding, effect modification, and causal inference through examples from infectious and non-communicable disease research in India. The course will also introduce students to systematic reviews and meta-analyses, diagnostic validity and demography. We will highlight how to interpret epidemiological evidence for program design and policy. Through discussions and practical exercises, students will learn to translate complex epidemiologic data into clear insights for real-world decision-making and scientific study.

Course content:
Study designs, Measures of occurrence, Measures of association, Measures of impact, Random and systematic error, Bias, confounding and effect modification, Introduction to systematic review and meta-analysis, Diagnostic Validity and Principles of demography.

The lab component of this course will include hands-on individual and group exercises on the following topics: Specific study designs, Systematic review & Meta analysis, Measures of disease frequency, Measures of association, Measures of impact, Confounding, Effect modification, Random & systematic error, Diagnostic validity, and Demographic indicators.

Manikanda Nesan S , Uttara Partap

Pre-requistes :
None

References : 1. Rothman, Kenneth J., Krista F. Huybrechts, and Eleanor J. Murray, Epidemiology: An Introduction, 3rd edn (New York, 2025; online edn, Oxford Academic, 21 Nov. 2024)

PU 203 (AUG) 2 : 1

Basic Biostatistics

The lectures in this course will cover the fundamentals of biostatistics relevant for public health. Topics covered will be: Types of data in public health, summarizing and visualizing data, Measures of central tendency, dispersion and correlation, Population and sample, Basics of probability, Probabilities in epidemiology, Random variables and parameters, Probability distributions (discrete and continuous), Sampling distributions, Theory of Estimation, Least squares estimation, Testing of hypothesis, Type 1 and Type 2 errors, Power and Sample size calculation, Analysis of variance, Resampling techniques.

The laboratory classes for PU203 will focus on quantitative problem solving in public health. This will include a) solving numerical problems related to the concepts taught in lectures, b) analyzing public health datasets using R/Python, c) visualizing and interpreting results from statistical inference, and d) carrying out power and sample size calculations.

Siddhartha Mandal

Pre-requistes : None

References : 1. Vu J and Harrington D. Introductory Statistics for the Life and Biomedical Sciences, First Edition Version date: August 8, 2021. (https://openintro.org/book/biostat/)

Division of Biological Sciences

Preface

This Division includes the Department of Biochemistry, Centre for Ecological Sciences, Department of Microbiology and Cell Biology, Molecular Biophysics Unit, Department of Molecular Reproduction, Development and Genetics, Centre for Neurosciences, Centre for Infectious Disease Research and the Central Animal Facility. Students from a variety of disciplines such as biology, chemistry, physics and medicine are admitted into the Division for research work leading to a PhD degree.

Each Department/Centre/Unit offers courses on specialized topics designed to provide students with the necessary theoretical background and introduction to laboratory methods. There are specific requirements for completing the Research Training Programme for students registering for research conferments at the Institute. For individual requirements, the students are advised to approach the Departmental Curriculum Committee.

The Department of Biochemistry offers a programme of study concentrating on a molecular approach towards understanding biological phenomena. The programme of instruction consists of lectures, laboratory work, and seminar assignments. In addition to formal course work, students are required to participate in group seminars, departmental seminars and colloquia.

The Center for Ecological Sciences has excellent facilities for theoretical as well as experimental research in plant and animal ecology and the social behavior of insects. The programme of instruction consists of lectures, laboratory work, seminars and special assignments.

The Department of Microbiology and Cell Biology offers courses in microbiology, infectious diseases, eukaryotic genetics, advances in immunology, plant and cell culture, and recent advances in molecular biology and genetic engineering. The students are expected to participate in seminars on recent advances in these fields.

The Molecular Biophysics Unit offers courses which cover recent developments in molecular biophysics, biopolymer conformation, structure and interactions of biomolecules and biophysical techniques.

The courses offered in the Department of Molecular Reproduction, Development and Genetics include those on endocrinology, reproduction signal transduction, genetics, gene expression and development.

The research interests in the Centre for Neuroscience spans from molecules to behavior. The courses offered would enable the students to gain fundamental knowledge in molecular and cellular neuroscience, systems and cognitive neuroscience. In addition, students will be expected to actively participate in seminars, journal clubs and lab rotations.

The Centre for Infectious Disease Research (CIDR) is involved in two primary activities: First, providing the intellectual and infrastructural support for infectious disease research. Second, enable researchers to perform studies in the Bio-safety Level-3 (BSL-3) facility, a state-of-the-art bio-containment space to perform research with high infectious organisms, e.g. Mycobacterium tuberculosis etc.

The Central Animal Facility provides standardized pathogen free, conventionally bred animals for biochemical experiments and also has facilities for research involving non-human primates.

Prof. Usha Vijayaraghavan

Dean,

Division of Biological Sciences

DB 225 (AUG) 0 : 6

Project - II

Tanweer Hussain

Pre-requisites : None

References : None

DB 201 (AUG) 2 : 0

Mathematics and Statistics for Biologists

Calculus: functions, limits and continuity, differentiation, integration,transcendental functions. Linear Algebra: vectors, matrices, determinants,linear equations. Statistics: elements of probability theory, discrete and continuous distributions, measures of central tendency, variability,confidence intervals, formulation of statistical hypotheses, tests of significance.

Balaji J,Shantanu P Shukla

Pre-requisites : None

References : None

Biochemistry

Preface

BC 203 (AUG) 3 : 0

General Biochemistry

Biochemistry of carbohydrates and lipids. Cell membrane: structure and function. Metabolism: basic concepts and design, glycolysis and citric acid cycle, oxidative phosphorylation, bioenergetics, fatty-acid metabolism,integration and regulation of metabolism,pentose phosphate pathways and gluconeogenesis. Photosynthesis.Protein translation and regulation, cellular protein transport and protein turnover, biosynthesis and catabolism of amino acids and nucleotides, signal transduction. DNA structure, replication and repair. Transcription, regulation of gene expression in prokaryotes and eukaryotes. Recombinant DNA technology.

Patrick D Silva , Debabrata Laha , Payel Roy

Pre-requistes : None

References : None

BC 306 (AUG) 3 : 0

Essentials in Immunology

Adaptive and innate immunity, inflammation, antibody structure and function,the complement system, antigen - antibody interaction,cells and organs of the immune system, B cell activation,immunoglobulin genes, molecular basis of antibody diversity, T cell receptors, T cell activation, major histocompatibility complex, antigen processing and presentation, lymphokines, transcription factors, hypersensitivity, autoimmunity, immunological techniques. Immunological disorders and therapy.

Dipankar Nandi , Kesavardana Sannula , Payel Roy

Pre-requistes :

References : None

BC 212 (AUG) 3 : 0

Essentials in Cell Biology

- Membrane structure and composition, transport, and trafficking
- Breakdown of macromolecules and energy generation
- Cell Cycle and its regulation
- The cytoskeleton and its role in cell shape, movement and diseases.

Part I (UT) : How molecular cell biology as a field evolved, contributions of notable scientists, signal peptide concept with emphasis on Gunter Blobel's work, steps in protein processing in the RER and Golgi, including protein folding, oligomerization, intracellular protein trafficking including lysosomal targeting.

Part II (DPN): Cell isolation and culture including 2D and 3D systems, Flow cytometry and cell imaging techniques, post translation modification and diseases, Nitrosative stress and oxidative stress, Endocytosis and receptor biology, including transferrin and LDL, autophagy, protein degradation pathways: lysosomal and ubiquitin-dependent and selected Nobel prizes in Cell Biology.

Part III (SP): The Cell Cycle and Cytoskeleton: Replication and Division: Witness the intricate choreography of the cell cycle, where cells meticulously replicate their DNA and divide to create new daughter cells. Different Cell Cycle stages, Cell cycle checkpoints. Explore the basic principles and mechanisms of the cytoskeleton, the internal scaffolding that provides structure and facilitates movement within the cell. Basic mechanisms for cell growth, cell death, cell specialisation, cell motility and interactions between cells and explain how these together facilitate the development of a multicellular organism.

Part IV (PDS): (A) Mitochondria Biogenesis: Introduction to mitochondria structure & function, Experimental Approaches, Outer and Inner membrane machinery, IMS and Matrix machinery. Protein Transport pathways: Signal sequence dependent, Outer membrane translocation, IMS region, Inner membrane: Conservative and STOP and Transfer pathways. Membrane protein insertion & biogenesis, Physiological significance (B) Mitochondrial Dynamics: Introduction, Fusion Machinery: Mitofusins: Mfn1, Mfn2 and OPA1 Fission Machinery: Dynamin-Related Protein 1 and Fis1 and other players Cell biology of Fusion and Fission Mechanisms, Experimental approaches, Physiological relevance, Disease pathogenesis. (C) Mitochondrial movement and positioning in axons: Anterograde movement of mitochondria in neurons, microtubule motors in mitochondrial motility in neurons and other cell types, Regulation of interaction between motor molecules and the organelle, motor-independent mechanisms for mitochondrial motility, Pathogenesis of neurological diseases. (D) Cross talk between Mitochondria and other organelles: Mitochondria and ER contact sites, Mitochondria & ER communication, structure of MAMs, & ERMES, retrograde signalling, Mitochondria, Peroxisome & Nuclear cross talk, Experimental approaches, metabolic disorders.

Dipankar Nandi , Patrick D Silva

Pre-requistes :

Basic background in biology (class 12 level) is required. The
References : References:

1. Lodish et. al. Molecular Cell Biology. Seventh Edition. Freeman Press.
2. Alberts, Morgan et al., Essentials in Cell Biology. Fifth Edition.

Ecological Sciences

Preface

The Center for Ecological Sciences has excellent facilities for theoretical, experimental and field based research in plant and animal ecology, evolution and behaviour. The programme of instruction consists of lectures, laboratory work, seminars and special assignments.

EC 301 (AUG) 2 : 1

Animal Behaviour : Mechanisms and Evolution

History and classical ethology; sensory processing and neural maps; Learningand memory; hormones and behavior; behavioral genetics; navigation and communication; optimality approaches and evolutionary models to understand strategies for foraging, competition, group living, sexual selection and mate choice, parental care and family conflicts, predator-prey interactions;theoretical, integrative and computational approaches to studying animal behaviour.

Rohini Balakrishnan , Kavita Isvaran

Pre-requistes : None

References : Alcock,J.,Animal Behaviour - An Evolutionary Approach(Sixth Edition),Sinauer Associates,1998~Neuroethology – J. M. Camhi (1984) Sinauer Associates,Sunderland~Behavioural Ecology: An Evolutionary Approach. J. R. Krebs & N. B. Davies (1991) Blackwell Press, Oxford~Sensory Ecology, Behaviour and Evolution by Martin Stevens (2013) Cambridge University Press

EC 305 (AUG) 2 : 1

Quantitative Ecology : Research Design and Inference

The scientific process in ecology; framing ecological questions; elements of study design; confronting ecological models with data; understanding the nature of data; statistical hypothesis testing; linear models, regression, ANOVA; generalised linear models; statistical modelling strategies.

Umesh Srinivasan

Pre-requistes : None

References : Hilborn,R. and Mangel,M., The Ecological Detective: Confronting Models with Data. Princeton University Press, Princeton~Zuur A, Ieno EN and GM Smith 2007 Analysing ecological data. Springer~Crawley MJ 2007 The R Book. John Wiley & Sons

EC 202 (AUG) 2 : 1

Ecology: Pattern and Process

History of ecology; interactions between organisms and the environment; ecological niche; distribution of species and communities; basic population biology; interspecific interactions; community assembly; diversity, richness and abundance; ecosystem structure and function; species concepts; ecological and evolutionary processes (dispersal and diversification); island biogeography; meta-population biology; macroecology.

Umesh Srinivasan

Pre-requistes : None

References : • A.E. Magurran, Measuring Biological Diversity, Blackwell Publishing, 2004. • J.H. Brown and M.V. Lomolino, Biogeography (Second Edition), Sinauer Associates, 1998. Pianka, E.R. Evolutionary Ecology. Eric R. Pianka, e-book, 2011.

EC 309A (AUG) 3 : 0

Ecosystems and Global Change

This course will be consist of lectures, readings and discussion, and a final class-project. It will have two 1-hr long sessions every week. In lectures, the instructor will cover topics related to ecosystem ecology, biogeochemical cycles, feedbacks between global change and ecosystem functions. The overall aim will be to introduce the different aspects of global change (e.g., rising CO2, altered precipitation, nutrient deposition, land-use and land-cover change, etc.) and their linkages with ecosystem functions. Through assigned readings, students will develop a broad understanding of how biogeochemistry provides a common premise to understand these linkages. Students will be evaluated upon their performance in a mid-semester exam, and a final class-project. The class-project is envisioned to be a review or synthesis (e.g., meta-analysis of primary literature) of a topic that is relevant to ecosystem ecology or global change.

Sumanta Bagchi

Pre-requistes :

No specific pre-requisites

References : Schlesinger WH, and E Bernhardt (2013). Biogeochemistry: An analysis of global change. 3rd ed, 688 pp. Academic Press. ISBN9780123858740. Chapin FS, PA Matson, and P Vitousek (2011). Principles of terrestrial ecosystem ecology. 2nd ed, 529 pp. Springer. ISBN9781441995025.

Neuroscience

Preface

NS 201 (AUG) 2 : 0

Systems Neuroscience

Neuronal biophysics, sensation & perception, motor systems

Aditya Murthy , S P Arun , Supratim Ray

Pre-requistes : None

References :

NS 202 (AUG) 2 : 0

Molecular and Cellular Basis of Behaviour

Neuroanatomy, neurotransmitter systems, synaptic transmission, pre- and post-synaptic organization and its relationship to synaptic physiology, synaptic plasticity, learning and memory.

Balaji J , Debasish Roy

Pre-requistes : None

References : None

NS 203 (AUG) 2 : 0

Cognitive Neuroscience

Methods in cognitive neuroscience, attention, decision making,executive functions, emotion, reward and motivation.

Sridharan Devarajan , Padmala Srikanth

Pre-requistes : None

References : None

NS 204 (AUG) 2 : 0

Developmental Neuroscience

Basic neuroanatomy of the central and peripheral nervous systems, neurogenesis, cell migration, cellular determination and differentiation, Neuronal growth cone and axon growth, Cell death in the nervous system, synapse formation,refinement of synaptic connections,astrocyte development and functions,oligodendrocyte development and functions, microglia development and functions.

Kavita Babu , Arnab Barik

Pre-requistes : None

References : None

NS 211 (JAN) 3 : 0

Optical Spectroscopy and Microscopy

Transition probabilities; Time dependent perturbation theory; Interaction with strong fields, Second Quantization; Origin of Spontaneous emission;characteristics of stimulated emission; Absorption and emission. Emergence of biophysical methods such as CD, Fluorescence spectroscopy, Energy transfer and other such methods from the above principles. Non-linear optics ; Lasers;Pulsed and CW lasers; Multi photon excitation; optical microscopy; diffraction limit; principles of laser scanning microscopes; photo detection; optical microscope in bits and pieces.

Pre-requistes : None

References : None

Microbiology and Cell Biology

Preface

MC 203 (AUG) 3 : 0

Essentials in Microbiology

Fascinating world of microbes; Principles of microscopy; Microbial taxonomy,Microbial diversity, evolution and genomics; Mechanisms of horizontal gene transfer including genome transplantation, Microbes as model systems of development, Microbes as bioreactors and sensors; bioremediation; bacterial cell structure and function; Bacterial physiology and nutrition;Bacteriophages, Plasmids and Transposons; Understanding and combating bacterial pathogenesis; Antibiotics mechanisms of drug resistance and mode of action; Quorum sensing and biofilms; Host-pathogen interactions and mechanisms of immune surveillance; PRR and their role in pathogenesis; TH subsets and modulation by pathogens; Diagnostics and vaccine development;Origin of cellular life; Biogeography of microbial diversity (is everything everywhere?); Host associated and free-living microbes; Mechanisms of microbial interactions; Causes, consequences, and evolution of physiological heterogeneity in bacterial populations; Bac

Amit Singh

Pre-requistes : None

References : "Stanier, R.V.,Adelberg E.A and Ingraham J.L., GENERAL MICROBIOLOGY, Macmillan Press, Fourth edition Westriech, G.A. and Lechmann M.D., MICROBIOLOGY,Macmillan Press, Fifth Edition Atlas R.M.,MICROBIOLOGY: FUNDAMENTALS AND APPLICATIONS, Macmillan Press Second Edition Goldsby, R. A.,Kindt T. J.,Osborne B. A., Kuby J.,IMMUNOLOGY, W. H. Freeman &

MC 203 (AUG) 3 : 0

Microbiology

Dipshikha Chakravortty

Pre-requistes : None

References : None

MC 206 (AUG) 2 : 0

RNA Biology

Mechanisms and machinery of transcription in prokaryotes and eukaryotes. RNAsplicing and editing. Catalytic RNAs. RNA-protein recognition and interactions. Transcriptional and translational regulation of gene expression. Ribosome heterogeneity. RNA granules and liquid liquid phase separation. mRNA decay in prokaryotes and eukaryotes. RNA modifications. RNA viruses & viroids, andtheir biology (Negative sense RNA Viruses, Positive Sense RNA Viruses,Retroviruses, Double Stranded RNA Viruses & Viroids). Small RNAs: biogenesis,and their modes of action in regulation of gene expression and chromatin architecture.

Saumitra Das , Purusharth Rajyaguru

Pre-requistes :

References : "Flint SJ, Enquist L, Racaniello V, Rall GF, Skalka AM. Principles of Virology. 4th ed. ASM Press; 2015. ISBN-10: 1555819338 Knipe DM,Howley PM . FieldsVirology. 6th ed. Lippincott: Williams and Wilkins; 2013. ISBN-10: 1451105630 For general RNA Biology: Any standard text book and The RNA World by Gesteland, Cech, and Atkins"

MC 208 (AUG) 2 : 0

Principles of Genetic Engineering

DNA, RNA, Proteins: composition, isolation, purification and quantification methods. Gene cloning, restriction and modification enzymes. PCR, RT-PCR, Site directed mutagenesis and Nucleic acid sequencing methods. Plasmid vectors including phagemid, cosmid for gene cloning and expression. Bacterial strains for Genetic engineering. Transformation, Transduction and Transfection methods. Preparation and characterization of DNA libraries. Nucleic acid Hybridization, nucleic acid-protein, Protein-protein interaction methods. Methods to modulate gene expression: SiRNA/shRNA technology. Lentivectors and Transduction. Viral genome engineering and applications in gene therapy and vaccines. Plant genetic engineering. Animal cloning and germline modifications. Genome editing by ZFN, TALEN. CRISPR/Cas Systems for DNA and RNA targeting. Genome wide CRISPR screening. Gene Drives and applications. Ethical and Safety issues of Genome editing

Shashank Tripathi , Naresh Loudya

Pre-requistes : None

References : J. Sambrook and D. W. Russell, Molecular Cloning: A Laboratory Manual, 3rd Edn: Vol. I, II, & III, Cold Spring Harbor Laboratory Press. J. J. Greene and V. B. Rao. Recombinant DNA Principles and Methodologies. CRC Press. S. B. Primrose and R. M. Twyman. Principles of Gene Manipulation and Genomics, 7th Edn, Blackwell Publishing. Fred Ausubel and Others. Current Protocols in

MC 212 (AUG) 2 : 0

Advances in Cell Biology

Concepts: Prokaryotic and eukaryotic membrane structure,composition, organization and transport; Organelle structure, function and their biogenesis includes nucleus, endoplasmic reticulum, Golgi,endosomes, lysosomes and lysosome-related organelles, autophagosomes,peroxisomes, mitochondria and chloroplasts; Protein trafficking in-and-out of the organelles; Cytoskeletal elements and organization; Cell adhesion and junctions; Intra and extra cellular signaling; Cell cycle, cell division (asymmetric and symmetric) and stem cells; Celldeath and protein homeostasis pathways and Cellular diseases.Methods:Introduction and evolution of light microscopy; Electron microscopy;Cytohistochemistry; Flowcytometry; Pulse-chase and subcellular fractionation;Proteomics and Protein-protein interaction approaches and genome-wide RNAi or small molecular screens to study the various cellular pathways.

Subba Rao Gangi Setty , Sachin Kotak

Pre-requistes : None

References : Molecular Biology of The Cell, Fifth edition, Alberts et al.

MC 205 (AUG) 2 : 0

Pathogen - Host interactions and immune evasion mechanisms

Pathogen - Host interactions and immune evasion mechanisms The vertebrate host has evolved numerous mechanisms to shield itself against the onslaught of the myriad pathogens around it. The host uses toll like receptors to recognize pathogens, and deploys effective weapons from its impressive arsenal to eliminate pathogens. This course will utilize multiple host-pathogen pairs as models to demonstrate the innumerable mechanisms utilized by pathogens of viral, bacterial and parasitic origin to subvert the host and enhance their own survival. Secretion systems of bacteria: Type I, II, III, IV, V overview of ABC exporters and importers, Plant Pathogen interactions (Xanthomonas Citrobactor, Erwinia); Virulence gene expression, intracellular athogenesis;Signaling by the bacterial components; Innate and adaptive immunity to bacterial pathogens; Quorum sensing, biofilm formation and its role in pathogenesis. Functional mimicry of host complement proteins, secretion of chemokine and cytokine –like molecules, inhibition of NF-?B and apoptosis, inhibition of serine proteases of the host antigen presenting cells to suppress antigen presentation, inhibition of inflammatory responses of the host seen in poxviruses, inhibition of MHC class I presentation of viral antigens by adenoviruses, inhibition of host secretory pathway by herpes viruses, prevention of phagosome acidification and other macrophage functions by Mycobacterium tuberculosis, antigenic variation and suppression of TH1 responses by protozoan pathogens will all be covered. Viral infectious cycle; Induction, regulation and mechanisms of Antiviral innate Immunity; Strategies of Viral evasion and antagonism of antiviral immunity; Mechanisms of Viral Pathogenesis. Interferon (IFN) is the cornerstone of antiviral innate immunity in mammalian cells. We will discuss detection of viral pathogens as foreign entity by mammalian cells, subsequent Interferon (IFN) induction and signaling, antiviral mechanisms of IFN Stimulated Genes (ISGs), Viral evasion and antagonism of IFN mediated immune response.

Balaji Kithiganahalli

Pre-requistes : None

References : (1) David G. Russell and Siamon Gordon,Phagocyte-Pathogen Interactions: Macrophages and the Host Response to Infection,ASM Press,2009. Knipe,D.M.~

MC 218 (AUG) 2 : 0

Advances in Molecular Biology

The course covers from the basic to the recent developemnts in the following topics: DNA structure, genome complexity, genome organization, DNA topology, DNA-protein interactions, chromatin structure and remodeling, DNA replication, RNA-Protein intearction, Transcription and its regulation, Mechanisms of DNA repair, RNA splicing, Catalytic RNAs, mRNA stability and editing, small mRNA mediated gene regulation, tRNA structure and function, Genetic code and its evolution, Translation regulation in eukaryotes and prokaryotes

Shovamayee Maharana

Pre-requistes :

Basic knowledge in General Microbiology and General Biochemistry

References : 1) Molecular Biology of the Cell (Latest Edition) by Bruce Alberts
2) Lewin's Genes XII by Jocelyn E Krebs, Eliott S Goldstein, Stephen T Kilpatrick
Unfortunately, I cannot add anything to SAP. The windows look inactivated.

Molecular Biophysics Unit

Preface

MB 204 (AUG) 3 : 0

Molecular Spectroscopy and its Biological Applications

Principles and biological applications of UV-Vis, fluorescence, vibrationaland circular dichroism spectroscopy. Mass spectrometry and basics of one- and two-dimensional NMR spectroscopy with applications to peptide and protein structure determination.

Siddhartha P Sarma

Pre-requistes : None

References : None

MB 206 (AUG) 3 : 0

Conformational and Structural aspects of biopolymers

Basic ideas on structure and conformation of simple molecules structural features of proteins and nucleic acids, aspects of biomolecular forces. Higher order structural organization of proteins and nucleic acid.

Anand Srivastava

Pre-requistes :

References : None

MB 207 (JAN) 2 : 0

DNA - Protein interaction, Regulation of gene expression, Nanobiology

Basic concepts on structural basis for macromolecular recognition. Concept ofcharge in macromolecules, specific and non-specific recognition, symmetry in DNA-protein recognition, structural ensembles, co-operativity, specific examples, story of lambda, restriction enzyme recognition, t-RNA synthetase recognition, promoter-RNA polymerase interaction, inducers and repressors,action at a distance. Single molecular paradigm. Methods to follow nanobiology. DNA-protein recognition at the level of single molecules.

Pre-requistes : None

References : None

MB 222 (AUG) 3 : 0

Electron microscopy and 3D image processing for Life sciences

Objectives and basic working principles of different types of microscopes. Different types of electron microscopies and their applications. Basic introduction of electron microscopy physics and optics. Principles of image formation, Fourier analysis, Contrast Transfer Function and point spread function (electron scattering, phase contrast, electron–specimen interactions, electron diffraction). Characteristics of various advanced sample preparation, imaging, data collection techniques of bio-molecules for negative staining and cryo-electron microscopy. Basic principles and introduction to single particle cryo-EM structure determination, including Random Conical Tilt Pair, Orthogonal Tilt pair, 3D reconstruction using cryo-electron tomography and sub-tomogram averaging. Latest advancements in methodologies for application to biological systems.

Somnath Dutta

Pre-requistes :

Basic knowledge in matrix, probability theory, basic physics
References : Books and references 1. John J. Bozzola and Lonnie D. Russell (1992). Electron Microscopy (Jones & Bartlett Publishers). 2. Ray F. Egerton (2005). Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM (Springer). 3. Elaine Evelyn Hunter and Malcolm Silver (1993). Practical Electron Microscopy: A Beginner's Illustrated Guide (Cambridge University). 4. Ludwig Reimer

MB 202 (AUG) 3 : 0

Introduction to Macromolecular X-ray Crystallography

Crystal morphology and symmetry. Symmetry elements and symmetry operations, point groups, lattice space groups. Production and properties of X-rays, diffraction of X-rays by crystals, Laue equations, Bragg'sLaw, Fourier transformation and structure factor, reciprocal lattice, experimental phasing methods . Basic ideas of structure determination, Patterson and Fourier methods, refinement procedures.

Aravind Penmatsa

Pre-requistes : None

References : Buerger M.J., Elementary Crystallography Woolfson M.M., An Introduction to X-ray Crystallography. Stout H. and Jenson L.H., X-ray Structure Determination, Macmillion, 1968. Macromolecular Crystallography- Benhard Rupp

MB 201A (AUG) 3 : 0

Introduction to Biophysical Chemistry

Basic concepts and laws of thermodynamics, ideal gases, ideal and non-ideal solutions, colligative properties, phase transitions, thermodynamics mixing, ligand binding and cooperativity in biological systems, kinetics. Students will study applications of equilibrium thermodynamics and kinetics to biological systems and obtain an understanding of the driving forces, directionality and rates in processes such as protein folding and biomolecular recognition.

Ashok Sekhar

Pre-requistes : None

References : 1) Tinoco, I., Sauer K., Wang J. C., Physical Chemistry, Principles and Applications in Biological Sciences, Prentice Hall, New Jersey,

2) Cantor, C.R., and Schimmel P.R., Biophysical Chemistry, Vols. I-III, W.H. Freeman and Co., San Francisco, USA, 1980.

Developmental Biology and Genetics

Preface

RD 214 (AUG) 2 : 0

Translational Oncology and Clinical Trial Design

Introduction to clinical oncology and research, Cancer staging grading and therapeutic choices, Translational research methodologies, Bench to bedside and bedside to bed: Forward and reverse translation, Attrition rates in oncology drug development, Defining clinical questions in laboratory-based research, Hypothesis driven vs hypothesis free discoveries for precision oncology, Biomarkers and patient stratification, Target identification using functional genetics and data-driven approaches, Target validation studies, Model systems for preclinical validation, Pharmacology basics for clinical studies, Sample size determination and statistics in study design, Phases of clinical trial, Types of clinical trial designs, Randomization and blinding, Precision medicine trials, Trial outcomes and analyses, Types of clinical data and analyses challenges, Regulatory authorities in Indian and global drug development, Data-driven translation in the digital AI era, Reverse translation of clinical data, Databases and tools for reverse translation, Trial operations and ethics, Translational medicine beyond Oncology, Case studies in personalized medicine, Guest lectures by medical oncologists and computational biologists.

Maya Raghunandan

Pre-requistes :
DB202 (general biology or equivalent), MC 207 (Molecular biology or equivalent), RD201 (Genetics or equivalent)

References : The biology of Cancer by Robert A. Weinberg
Oncology Clinical trials by William Kevin Kelly & Susan Halabi
Clinical trial design and statistics by Lawrence M Friedman et al.

Life Sciences

Preface

The MSc Life Sciences program is comprised of comprehensive foundational course work combined with a vast selection of electives, leading towards a specialisation in one of five fields of Biology. Students also have labs designed to introduce them to tools and techniques, as well a lecture series and workshops for broader skill development. In the final year, students engage in independent research projects that result in an MSc thesis.

LS 102 (AUG) 1 : 0

Opportunities and Extensions in Life Sciences - Pa

This course is deigned to expose students enrolled in the MSc in Life Sciences programme to opportunities and extensions in the field of biological sciences. The course will be conducted as a series of lectures and workshops by invited guests on topics, such as, IP/ patent laws; Humanities, including science history; Innovation and Entrepreneurship; Artificial intelligence and data analytics; Science Policy, governance and management; opportunities and pitfalls in BioMedical Research; Sci-Art in the alternative medium; Science communication and journalism; including Ethical use of animals & their care; Biosafety and practice.

The course will span two semesters and each month will be devoted to one of the eight numbered topics above. Invited guests will conduct 2-3 lectures / workshop a month (1 hour each) and students will have an assignment or a presentation to conduct for each of the topics that will involve independent research. For example, for the Science Communication session, students will interact with science journalists and will learn how to write a science news article. For the Innovation and Entrepreneurship session, students will meet a biomedical entrepreneur and will be asked to present a business model for a hypothetical biomedical product. Assignments will therefore range from written reports to presentations in class during the month devoted to the session.

Deepak Kumar Saini , Maria Thaker

Pre-requistes : None

References : will be provided

LS 209 (AUG) 0 : 2

Laboratory course in Molecular Techniques

bacterial culturing, vectors, DNA isolation, transformation, cloning, expression and purification of proteins; characterization by western blotting/ ELISA; cell culture, transfection, stable line generation, gene expression analysis by RT-PCR; fluorescence microscopy, immunofluorescence; viability assessment; Alamar blue / MTT assay; flow cytometry and cell sorting. Biophysical techniques - Concept of absorption and spectroscopy. Concept of protein/nucleic acid folding (CD and Fluorescence); Separation of protein and identification (Chromatography and Mass spectrometry); Bioinformatics.

Meetali Singh

Pre-requistes : None

References : Wilson And Walker's Principles And Techniques Of Biochemistry And Molecular Biology

Division of Chemical Sciences

Preface

The Division of Chemical Sciences comprises of the Department of Inorganic and Physical Chemistry (IPC), Materials Research Centre (MRC), Department of Organic Chemistry (OC) and Solid State and Structural Chemistry Unit (SSCU). Students with a basic/advanced degree in Chemistry, Physics, Biology, or many branches of engineering are eligible for admission to the doctoral program. In addition, the division also admits B.Sc. graduates to the Integrated PhD program. Since 2011, the division is also actively engaged in the four-year Bachelor of Science (Research) program and has introduced several courses at the undergraduate level.

The courses offered by various departments carry a two-letter departmental code that is followed by a three digit number; of which, the first digit refers to the course level. In addition, courses offered to the Integrated PhD students are listed separately with another code. The courses offered by the different departments have been grouped as follows:

CD Integrated Ph D

IP Inorganic and Physical Chemistry

MR Materials Research Centre

OC Organic Chemistry

SS Solid State and Structural Chemistry

Each department/centre/unit offers courses on basic as well as specialized topics designed to provide students with a sound foundation in both theoretical and experimental aspects. There are specified requirements for completing the research training programme (RTP) for students registering under various streams at the Institute. For details concerning these requirements, students are advised to approach the Chair of the Department/Centre/Unit.

The Department of Inorganic and Physical Chemistry provides training in several contemporary areas of theoretical and experimental research, covering all aspects of modern Inorganic and Physical Chemistry. The programme of instruction consists of class lectures, laboratory work and student seminars.

The Materials Research Centre provides students opportunity to learn and train on several modern sophisticated instrumental facilities for the materials preparation, device fabrication and materials and device characterization. The Centre offers courses in various aspects of theoretical and experimental Material Science and on modern materials characterization techniques.

The Department of Organic Chemistry offers courses at both the fundamental and advanced levels in Organic Chemistry, in addition to courses on advanced special topics. The students also undergo training in advanced laboratory methods and are expected to give seminars on contemporary research topics.

The Solid State and Structural Chemistry unit offers several courses in frontier areas of Solid State Chemistry and Surface Sciences, besides basic and advanced courses in Chemical Physics; students of the department will have an opportunity to work in all major topics in solid state chemistry and physics.

Prof. G. Mugesh

Dean

Division of Chemical Sciences

CD 213 (AUG) 3 : 0

Organic Chemistry – Structure and Reactivity

Stereochemistry and conformational analysis. Methods of deducing organic reaction mechanisms, Hammond postulate,Curtin-Hammett principle, linear freeenergy relationships; Hammett equation; kinetic isotope effects. Electronic effects in organic compounds, aromaticity,frontier orbital theory, steric effects;organic transformations and molecular rearrangements; reactive intermediates, classical and nonclassical carbocations, carbanions, free radicals, carbenes, nitrenes, arynes,radical ions, diradicals,concerted reactions,Woodward- Hoffman rules.

Santanu Mukherjee,Garima Jindal

Pre-requisites : None

References :

Anslyn,E.V.,and Dougherty,D.A.,Modern Physical Organic Chemistry

CD 211 (AUG) 3 : 0

Physical Chemistry – I Quantum Chemistry and Group Theory

Postulates of Quantum Mechanics and introduction to operators; Wave Packets,Exactly solvable problems Perturbational, Variational,and WKB Methods;Angular Momentum and Rotations, Hydrogen Atom, Zeeman and Stark effects, Manyelectron Atoms, Slater determinants, Hartree-Fock Variational Method for atoms; Symmetry and Group theory,Point Groups, Reducible and Irreducible Representations (IR), Great Orthogonality theorem, Projection operators,Applications to molecular orbitals and normal modes of vibration and selection rules in spectroscopy.

Abhishek Sirohiwal

Pre-requisites : None

References : I. Levine,Quantum Chemistry,D. Griffiths,Introduction to Quantum Mechanics.,F.A. Cotton

CD 214 (AUG) 3 : 0

Basic Mathematics

Multivariable Calculus (6): Exact and inexact differentials, partial derivatives, multi-dimensional integrals, numerical integration; Vector Calculus (6): Gradient, divergence, and curl and their physical significance, Green’s theorem and Stokes’ theorem; Maxima/Minima (3): Maxima/minima of multivariable functions with constraints (Lagrange multipliers); Series of Functions (3): Taylor series and Maclaurin series; Linear Algebra (6): Matrices, matrix eigen value problems, vector spaces; Differential Equations (6): Differential equations of quantum chemistry and chemical kinetics, numerical solutions of differential equations; Transformations (4): Dirac delta function, orthonormal functions, Fourier series, Fourier transforms, Laplace transforms and Legendre transforms; Probability and Statistics (8): Conditional probability, discrete and continuous random variables, mean and variance, moments of probability distributions, covariance and correlations, law of large numbers, central limit theorem, normal distribution, Poisson distribution, error propagation, curve fitting, and confidence intervals.

Sai G Ramesh

Pre-requisites : None

References : H. Margenau and G. Murphy, The Mathematics of Physics and Chemistry; M. L. Boas, Mathematical Methods in the Physical Sciences; G. B. Arfken, H. J. Weber and F. E. Harris, Mathematical Methods for Physicists

CD 215 (AUG) 0 : 4

Organic & Inorganic Chemistry Laboratory

Common organic transformations such as esterification,Diels-Alder reaction,oxidation-reduction, Grignard reaction, etc.Isolation and purification of products by chromatographic techniques,characterization of purified products by IR and NMR spectroscopy.Synthesis of coordination complexes, preparation of compounds of main group elements, synthesis of organo-metallic complexes.Physico-chemical characterization of these compounds by analytical and spectroscopic techniques.

Jayaraman N,Partha Sarathi Mukherjee,Abhishake Mondal

Pre-requisites : None

References : None

CD 402 (AUG) 3 : 0

Molecular Spectroscopy, Dynamics and Photochemistry

Energy levels of molecules and their symmetry. Polyatomic rotations and normal mode vibrations. Electronic energy states and conical intersections; time-dependent perturbation theory and selection rules; microwave, infrared and Raman, electronic spectroscopy; energy transfer by collisions, both inter and intra-molecular. Unimolecular and bimolecular reactions and relations between molecularity and order of reactions, rate laws; temperature and energy dependence of rate constants, collision theory and transition state theory, RRKM and other statistical theories; photochemistry, quantum yield,photochemical reactions, chemiluminescence, bioluminescence, kinetics and photophysics.

Soumen Ghosh

Pre-requisites : None

References : None

CD 212 (AUG) 3 : 0

Inorganic Chemistry – Main group and coordination chemistry

Unusual bonding in hyper- and low valent compounds. Multiple bonding in main group compounds. Chains, rings, and cage. Main group organometallics. Chemistry of Group 8 elements. Coordination chemistry: Spectral properties; Orgel diagrams; Tanabe- Sugano diagrams; Magnetic properties; inorganic reactions and mechanisms: hydrolysis reactions, substitution reactions trans-effect; isomerization reactions, redox reactions; metal-metal bonding and clusters; mixed valence systems.

Geetharani K,Abhishake Mondal

Pre-requisites : None

References : Shriver D.F, Atkins P.W. and Langford C.H., Inorganic Chemistry,Freeman, NY Cotton F.A. and Wilkinson G. Advanced Inorganic Chemistry, 6th edition, Wiley, 2007. Huheey J.E., Inorganic Chemistry, Principles of Structure and Reactivity, Pearson, 4th edition. 2006.

Inorganic and Physical Chemistry

Preface

IP 203 (AUG) 3 : 0

Group Theory and Molecular Spectroscopy

Group theory: Symmetry elements, point groups, representation theory, great orthogonality theorem, SALCs. Time-dependent perturbation theory, light-matter interaction. H-like atoms, angular momenta and selection rules of transitions, multi-electon atoms, term symbols, spin-orbit coupling, Zeeman and linear Stark effects. Rotations and vibrations of diatoms, anharmonic effects, selection rules, electronic structure. Rotations and vibrations of polyatomic molecules, various tops and their properties, normal modes of vibration, selection rules, electronic states and transitions

Anoop Thomas

Pre-requistes : None

References : (1) I. N. Levine, Molecular Spectroscopy. (2) W. S. Struve, Fundamentals of molecular spectroscopy (3) P. F. Bernath, Spectra of atoms and molecules (2nd Ed.). (4) F. A. Cotton, Chemical Applications of Group Theory

IP 311 (AUG) 3 : 0

Bio and Medicinal Inorganic Chemistry

Principles of biochemistry and molecular biology, role of metal ions in biology, principles of coordination chemistry, amino acids and other bioligands, proteins – secondary and tertiary structure, nucleic acids, iron proteins, iron transport, role of zinc in biology – zinc enzymes, biological importance of nickel, copper proteins, redox reactions involving manganese, biological roles of vanadium, cobalt and molybdenum, basic concepts in drug design, metals and health -metal based drugs and mechanism of their action, metalloproteins as drug targets.

Debasis Das

Pre-requistes : None

References : S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry (University Science Books, California)

IP 312 (AUG) 3 : 0

Advanced Organometallic Chemistry

Structure and bonding in organometallic compounds; reaction types; classes of organometallic compounds: Main-group, transition metal, lanthanide and actinide compounds. Isolobal analogies, metal-metal multiple bonding in organometallic compounds and metal clusters. Organometallic catalysis: hydrogenation, C-C coupling, C-S coupling, hydroboration and hydrosilylation, C-H activation

Balaji R Jagirdar

Pre-requistes : None

References : Ch. Elschenbroich, Organometallics (3rd edition, Wiley-VCH, Weinheim)

Materials Research Centre

Preface

MR 309 (AUG) 3 : 0

Introduction to Supramolecular Chemistry

Course description: Supramolecular chemistry is “chemistry beyond the molecule”. It is an interdisciplinary field that covers the physical, chemical and biological properties of complex chemical species held together mainly by non-covalent interactions. This course provides an introduction to the field, and discusses the intermolecular forces that dictate the formation of supermolecules and supramolecular assemblies and their properties. In addition, current trends are discussed using recent publications in this area. Course outline: This course is designed to be modular and includes the following topics: Molecular recognition, Host-Guest Chemistry; Receptors, Coordination and the “Lock and Key” Analogy; Chelate, Conformational and Macrocyclic Effects; Pre- organisation and Complementarity; Thermodynamic and Kinetic Selectivity; Selectivity and Solution Behaviour of Crown Ethers,Cryptands,Spherands; Complexation of Organic Cations; Biological anion receptors; Anti- crowns.

Subinoy Rana

Pre-requistes : None

References : Supramolecular Chemistry. J. W. Steed, J. L. Atwood, John Wiley and Sons,2000. • Supramolecular Chemistry. Concepts and Perspectives. J. - M. Lehn. VCH, 1995. • Principles and Methods in Supramolecular Chemistry. H.-J. Schneider,A.Yatsimirsky, John Wiley and Sons.

MR 310 (AUG) 3 : 0

Light emitting materials and devices

Introduction to organic light-emitting diodes (OLEDs), PLEDs, Pervoskite-LEDs and their application, color science, basic working principles of light emitting devices, device fabrication and characterization, practical demonstration of device fabrication. Design, synthesis and characterization of hole injection/transporting, electron injection/transporting and host materials. Types of emitting materials: fluorescence, phosphorescence, TTA, TADF, singlet fission, perovskite, and carbon dots and their application in light emitting devices. Dendrimers and dendronized polymers for light emitting devices. Practical demonstration of device fabrication in the laboratory.

Rajamalli P

Pre-requistes : None

References : 1. OLED Fundamentals (Materials, Devices, and Processing of Organic Light-Emitting Diode) by Daniel J. Gaspar and Evgueni Polikarpo 2. Organic light- emitting diodes (OLEDs) by Alastair Buckley 3. Color Vision and Colorimetry Theory and Applications by Daniel Malacara 4. Dendrimers and Other Dendritic Polymers (by Jean M. J. Fréchet and Donald A. Tomalia)

Organic Chemistry

Preface

OC 231 (AUG) 3 : 0

Chemistry of Proteins and Peptides

Amino acids, peptide synthesis, geometry and oligopeptide conformations. Non-covalent interactions, dynamism in peptides, molecular recognition, Ramachandran plot, Foldamers. Protein architecture, protein-protein interactions, protein stability. Peptide conformational analysis. Protein solubility, pKa, protein aggregates, isofolding, unfolded proteins, membrane proteins. Peptidomimetics, isosteres, folding peptides. Enzymes: mechanisms of selected enzymes, enzyme inhibitors. Important developments in current literature.

Erode N Prabhakaran

Pre-requistes : None

References : Voet D and Voet J.G. Biochemistry 2nd Edition John Wiley Cysons NY,1995.,Stryer L. Biochemistry 4th Edition,WH. Freeman & Co.,N

OC 301 (AUG) 3 : 0

Organic Synthesis II

Organic synthesis and total synthesis of complex natural products: Advances in C-C bond forming reactions; Olefination reactions; Olefin metathesis including alkyne metathesis; Synthesis of alkynes; Asymmetric addition of Grignard reagents, organozinc and lithium reagents to carbonyl compounds; Directed lithiation, chiral lithium reagents; alkylation of carbonyl compounds including asymmetric alkylation. Addition of organometallinc reagents to imines, Asymmetric acetate/ propionate aldol reaction. Asymmetric allylation of carbonyl compounds; Ring forming reactions, Baldwin rules;cyclopentannulations with specific application to triquinanes. Advances in carbocation rearrangements. Inverse electron demand Diels Alder reaction/Hetero Diels Alder reaction: Application of the above in the total synthesis of natural products including natural products of contemporary interest in current literature.

Kavirayani R Prasad

Pre-requistes : None

References : Wyatt P. and Warren S,Organic Synthesis,Strategy and Control,; Wiley 2007,Nicolaou.

OC 302 (AUG) 3 : 0

Asymmetric Catalysis: From Fundamentals to Frontiers

Basics of asymmetric catalysis including energetics of reactions;Lewis acid &cLewis base catalysis; Kinetic, Dynamic Kinetic and Parallel Kinetic Resolution; Desymmetrization reactions; Mechanistic studies of asymmetric reactions:cnonlinear effects, autocatalysis and autoinduction; Bifunctional, Dual and Multifunctional catalyst systems; Modern aspects of asymmetric catalysis:counterion-directed catalysis, cooperative, dual and merged catalysis,asymmetric photocatalysis etc.Applications of asymmetric catalysis.

Akkattu T Biju

Pre-requistes : None

References : Walsh,P.J.,Kozlowski,M.C.,Fundamentals of Asymmetric Catalysis

Solid State and Structural Chemistry

Preface

The Solid State and Structural Chemistry Unit was founded in November 1976 by Bharat Ratna Professor C. N. R. Rao. SSCU has provided major thrust to diverse frontier areas at the intersection of Chemistry, Physics and Biology. Since its beginning, SSCU has fostered a culture of excellence, and it leads IISc in terms of research quality and productivity. The department's research is highly interdisciplinary, spanning frontier areas at the intersection of Chemistry, Physics and Materials Science.

The unit offers graduate level courses in Quantum Chemistry, Advanced Statistical Mechanics, Electrochemistry, Photovoltaics, Energy Research and Crystallography.

SS 201 (AUG) 3 : 0

Thermodynamics and Statistical Mechanics

Formal principles; conditions for equilibrium, Legendre transformation, Maxwell relations. Phase transitions; classification,Landau theory, universality. Irreversible thermodynamics; thermodynamic forces and fluxes.Onsager relations; illustrative applications to electrochemistry; thermo-electric and thermo-magnetic effects. Introduction to far from equilibrium systems. Basic formulations of statistical mechanics; ensembles, partition functions, relations to thermodynamic functions. Ideal systems; quantum statistics, non-ideal gases, Einstein and Debye Solids. Introduction to statistical mechanics of liquids. Computer simulations; basics of Monte Carlo and molecular dynamics techniques.

P Govardhan Reddy

Pre-requistes : None

References : None

SS 202 (AUG) 3 : 0

Introductory Quantum Chemistry

Basic postulates of quantum mechanics. Exact solutions:harmonic oscillator (ladder operator approach), particle on a ring and a sphere. Linear operators and matrices. Angular momentum, raising and lowering operators and matrices for spin angular momentum. Hydrogenic atoms (without explicit solution of radial equation), many electron atoms and Slater determinants. Approximate methods - perturbation methods, application to many-electron atoms and term symbols. Variational method - Hartree-Fock method for atoms.Hartree-Fock-Roothan method for molecules. Time-dependent perturbation method - absorption and emission.

Awadhesh Narayan

Pre-requistes : None

References : None

SS 209 (AUG) 3 : 0

Electrochemical Systems

A large section of the course will be dedicated to principles of electrochemistry which form the foundation of advanced electrochemical systems. A primer to electrochemical fundamentals will be provided to ensure that the course is self-contained with a minimum of pre- requisites. The course will cover electrochemical systems such as batteries, fuel cells, electrochemical transistors,nanoelectrochemical devices such as memristors and elementary electrolyte theory and its applications to confined nano-scale systems.

Naga Phani B Aetukuri

Pre-requistes : None

References : Electrochemical Methods: Fundamentals and Applications by Bard and Faulkner~Electrochemical Systems by Newman and Thomas-Alyea~Advanced Batteries by Huggins

SS 304 (AUG) 3 : 0

Solar Energy: Advanced Materials and Devices

Important Parameters in Photovoltaics, Shockely-Queisser limit, thermodynamic aspects, photon management. Mechanisms of charge separation and transport:junctions, energy transfer, electron transfer. Advanced Photovoltaic Materials (Perovskite, DSSC, Polymer and Colloidal Nanocrystal), Factors affecting photovoltaic performance-exciton diffusion length, charge transport and band-gap. Organic photovoltaic cells-Schottky, Donor-acceptor, heterojunction and bilayer. Methods of photovoltaic Fabrication and photophysics of molecular sensitizers.

Satish Amrutrao Patil

Pre-requistes : None

References : The Physics of Solar Cell-Jenny Nelson,Imperial College Press,Organic Photovoltaics Mechanisms,Materials and Devices-NiyaziSerdar Sariciftci, Physics of Semiconductor Devices-Sze and Ng.

SS 307 (AUG) 3 : 0

Magnetic Resonance and Quantum Technologies

Aim of the Course: This course provides a rigorous introduction to spin-based magnetic resonance and quantum technologies, with emphasis on the quantum dynamics of spins, magnetic resonance spectroscopy, dynamic nuclear polarization, and quantum sensing. The course connects theory, computation, and applications in materials characterization and spin-based metrology.

Intended Learning Outcomes
1. Construct spin Hamiltonians for nuclear and electron spin systems and analyze their spectra and dynamics.
2. Use density-matrix and product-operator formalisms to describe spin evolution in magnetic resonance experiments.
3. Solve the Liouville-von Neumann equation for static, pulsed, and periodically driven Hamiltonians.
4. Interpret the roles of Zeeman, chemical shift, g-tensor, dipolar, J-coupling, quadrupolar, hyperfine, and zero-field splitting interactions in Nuclear Magnetic Resonance (NMR) and Electron Paramagnetic Resonance (EPR).
5. Explain the principles of, NMR, EPR, Dynamic Nuclear Polarization (DNP), Optical Detected Magnetic Resonance (ODMR), and NV-center-based quantum sensing.
6. Simulate spin dynamics and spectra using SIMPSON, EasySpin, and Python-based workflows.
7. Design and critically evaluate pulse sequences and sensing protocols for spectroscopy and magnetometry.

Curriculum / Syllabus
Foundations of Spin Quantum Mechanics (4): Angular momentum and spin operators; Pauli matrices; spin-1/2 and higher-spin systems; Zeeman interaction; Larmor precession; rotating frame; classical vector model and its limitations; ensembles, populations, and coherences.
Spin Hamiltonian, Density Matrix and Product Operator Formalism (4): Construction of spin Hamiltonians; density operator and equilibrium density matrix; high-temperature approximation; product operators; expectation values and observables; description of coupled-spin systems.
Internal Interactions and Their Spectroscopic Signatures (4): Chemical shift and chemical shift anisotropy; dipolar couplings; scalar J-couplings; quadrupolar interactions; g-anisotropy, hyperfine interaction, zero-field splitting; orientation dependence, tensors, powder patterns, and magic-angle spinning.
Time Evolution of Spins (4): Schrodinger and Liouville pictures; Liouville-von Neumann equation; propagators for time-independent and time-dependent Hamiltonians; interaction frame/toggling frame; action of RF and microwave pulses.
Average Hamiltonian and Floquet Theory (5): Magnus expansion; average Hamiltonian theory; periodic driving; Floquet description of driven spin systems; recoupling and decoupling; treatment of MAS and periodically modulated Hamiltonians.
Pulse Sequences, Coherence Transfer and Multidimensional Spectroscopy (6): Coherence order; phase cycling; pulsed field gradients; basic liquid-state NMR pulse sequences; coherence transfer; multidimensional NMR concepts; pulsed EPR sequences such as spin echo, ESEEM, and HYSCORE.
Relaxation and Decoherence (5): Longitudinal and transverse relaxa

Sheetal Kumar Jain

Pre-requisites :
1. CD 211: Quantum Chemistry and Group Theory or equivalent
2. CD 214:

References : 1. Levitt, M. H., Spin Dynamics
2. Duer M. J., Solid-State NMR Spectroscopy: Principles and Applications
3. Schweiger A., and Jeschke G., Principles of Pulse Electron Paramagnetic Resonance

Chemical Science

Preface

CY 215 (AUG) 0 : 3

Advanced Laboratory - 1

Separation of Plant Pigments- Introduction to Thin-layer Chromatography and Column Chromatography; Synthesis of Methyl Benzoate (acid catalysed esterification); Triphenylcarbinol from Phenyl Magnesium Bromide and Methyl Benzoate (Grignard Reaction); Diels-Alder Reaction between Cyclopentadiene and Maleic anhydride; Benzoylation of Amino acid (Schotten-Baumann Reaction); Synthesis of 1,2,3,4,6-penta-O-acetyl glucopyranose; Water mediated Wittig Reaction – synthesis of cinnamates; Benzoin to Benzil; Benzil to Benzilic acid Rearrangement; Clemmenson reduction: Nitrobenzene to N-phenyl hydroxyl amine; Darzen's glycidic ester condensation: Benzaldehyde, ethyl bromoacetate, KOH, benzyltriethylammonium chloride; Synthesis and characterization of acetyl ferrocene; Synthesis and characterization of H2TPP, Ni/Cu/Zn-TPP complexes; Synthesis and characterization of HKUST-1; Synthesis and characterization of the polyoxometalate complexes and grafting the Amino Group; Synthesis and Use of a Nic

Partha Sarathi Mukherjee , Abhishake Mondal

Pre-requistes : None

References : (1) A collection of interesting general chemistry experiments, Elias AJ, Universities Press, 2008 (2) Macroscale and Microscale Organic Experiments, Williamson KL and Masters K, Brooks/Cole, 2nd Edition, 2016 (3) A Small Scale Approach to Organic Laboratory Techniques, 3rd Edition, Pavia DL, Lampman GM, Kriz GS and Engel RG, Brooks/Cole Pub Co, 3rd edition, 2010 (4) College

Division of EECS

Preface

The Division of EECS comprises the Departments of Computer Science and Automation (CSA), Electrical Communication Engineering (ECE), Department of Electronic Systems Engineering (ESE), and Electrical Engineering(EE). The courses offered in these departments have been grouped into the following technical areas identified by the following codes, which appear as prefixes to the course numbers.

E0 Computer Science and Engineering

E1 Intelligent Systems and Automation

E2 Communication Systems

E3 Electronic Devices, Circuits and Technology

E4 Power and Energy Systems

E5 High Voltage and Insulation Engineering

E6 Power Electronics and Drives

E7 Photonic Devices, Circuits and Systems

E8 Electromagnetic, Microwaves and Antennas

E9 Signal Processing, Acoustics and Bioengineering

All the departments in the Division provide facilities for research leading to the PhD and the M Tech (Research) degrees. The following course-based Master's programs are offered individually or jointly by the departments of the Division.

M Tech in Electrical Engineering (EE)

M Tech in Communication and Networks (ECE)

M Tech in Computer Science and Engineering (CSA)

M Tech in Electronics Systems Engineering (ESE)

M Tech in Artificial Intelligence (CSA,ECE,EE,ESE)

M Tech in Signal Processing (EE and ECE)

M Tech in Microelectronics and VLSI Design (ECE and ESE)

The dissertation projects in the above M Tech programs are numbered EE 299, CN 299, CS 299, ES 299, Ai 299, SP 299, and MV 299, respectively. We wish all the students a lively and intellectually rewarding experience in the Division of EECS at the Indian Institute of Science.

Prof. Rajesh Sundaresan

Dean

Division of EECS

Computer Science and Automation

Preface

E0 238 (AUG) 3 : 1

Intelligent Agents

Introduction to Artificial Intelligence, Problem solving, knowledge and reasoning, Logic, Inference, Knowledge based systems, reasoning with uncertain information, Planning and making decisions, Learning,Distributed AI,Communication, Web based agents, agents, Artificial Intelligence Applications and Programming.

Pre-requistes : None

References : S.Russel and P. Norvig,Artificial Intelligence - A Modern Approach, Prentice Hall, 1995. George F.Luger, Artificial Intelligence, Pearson Education, 2001.Nils J. Nilsson,Artificial Intelligence - A New Synthesis, Morgan Kaufmann Publishers, 2000.

E0 225 (AUG) 3 : 1

Design and Analysis of Algorithms

Greedy algorithms, divide and conquer strategies, dynamic programming, max flow algorithms and applications, randomized algorithms, linear programming algorithms and applications,NP-hardness, approximation algorithms, streaming algorithms. References: Kleinberg and Tardos, Algorithm Design, Addison Wesley, 2005. Cormen, Leiserson, Rivest, and Stein, Introduction to Algorithms, 3rd Edition, Prentice Hall, 2009.

Anand Louis , Rahul Saladi

Pre-requistes : None

References : None

E0 227 (AUG) 3 : 1

Program Analysis and Verification

Dataflow analysis: Lattices, computing join-over-all-paths information as the least solution to a set of equations that model the program statements,termination of dataflow analysis, analysis of multi-procedure programs.Abstract interpretation of programs: Galois connections, correctness of dataflow analysis. Pointer analysis of imperative programs. Program dependence graphs, and program slicing. Assertional reasoning using Hoare logic. Type Systems: Monomorphic and polymorphic type systems, Hindley-Milner's type inference algorithm for functional programs.

Deepak D'Souza , Raghavan K V

Pre-requistes : None

References : Flemming Nielson,Hanne Riis Nielson, and Chris Hankin: Principles of Program Analysis, Springer, (Corrected 2nd printing, 452 pages, ISBN 3- 540-65410-0), 2005. Benjamic Pierce: Types and Programming Languages, Prentice-Hall India, 2002.

E0 230 (AUG) 3 : 1

Computational Methods of Optimization

Need for unconstrained methods in solving constrained problems. Necessaryconditions of unconstrained optimization, Structure of methods, quadratic models. Methods of line search, Armijo-Goldstein and Wolfe conditions for partial line search. Global convergence theorem, Steepest descent method.Quasi-Newton methods: DFP, BFGS, Broyden family. Conjugate-direction methods: Fletcher-Reeves, Polak-Ribierre. Derivative-free methods: finite differencing. Restricted step methods. Methods for sums of squares and nonlinear equations.Linear and Quadratic Programming. Duality in optimization.

Chiranjib Bhattacharyya

Pre-requistes : None

References : Fletcher R., Practical Methods of Optimization, John Wiley, 2000.~

E0 232 (AUG) 3 : 1

Probability and statistics

Anant Raj

Pre-requistes : None

References : None

E0 235 (AUG) 3 : 1

Cryptography

Elementary number theory, Finite fields, Arithmetic and algebraic algorithms,Secret key and public key cryptography, Pseudo random bit generators, Block and stream ciphers, Hash functions and message digests, Public key encryption,Probabilistic encryption, Authentication, Digital signatures, Zero knowledge interactive protocols, Elliptic curve cryptosystems, Formal verification,Cryptanalysis, Hard problems.

Arpita Patra

Pre-requistes :

References : Stinson. D.Cryptography: Theory and Practice.   Menezes. A. et. al. Handbook of Applied Cryptography.

E0 240 (AUG) 3 : 1

Modeling and Simulation

Sumit Kumar Mandal

Pre-requistes : None

References : None

E0 243 (AUG) 3 : 1

Computer architecture

Processor Architecture: Instruction-Level Parallelism,Superscalar and VLIW architecture; Multi-core processors;Memory Subsystem: Multilevel caches,Caches in multi-core processors,Memory controllers for multi-core systems;Multiple processor systems: shared and distributed memory system,memory consistency models, cache coherence, and Interconnection networks;Advanced topics in architecture.

Arkaprava Basu , Sanchari Sen

Pre-requistes : None

References : None

E0 253 (JAN) 3 : 1

Operating Systems

User Level Specification of OS. Fundamental Concepts of Multiprogrammed OS, Basic Concepts and Techniques for Implementation of Multiprogrammed OS. Processes and the Kernel, Microkernel Architecture of OS. Multiprocessor,Multimedia, and Real-Time OS. POSIX Standards. Management and Control of Processes. Basic Concept ofThreads, Types of Threads, Models of Thread Implementations. Traditional and Real-Time Signals. Clocks, Timers and Callouts. Thread Scheduling for Unix, Windows, and Real-Time OS, Real-Time Scheduling.Interprocess/Interthread Synchronization and Communication, Mutual Exclusion/Critical Section Problem, Semaphores, Monitors, Mailbox, Deadlocks.Concepts and Implementation of Virtual Memory(32-bit and 64-bit), Physical Memory Management. File Organization, File System Interface and Virtual File Systems, Implementation of File Systems. I/O Software:Interrupt Service Routines and Device Drivers. Protection and Security. Case Study of Unix,Windows, and Real-Time OS.

Pre-requistes : None

References : None

E0 256 (AUG) 3 : 1

Theory and Practice of Computer Systems Security

This course will seek to equip students with the fundamental principles and practice of computer systems security. The course will cover the major techniques of offense and defense, thereby educating students to think both as attackers and defenders. By the end of the course, students will have been exposed to the state of the art, and will be equipped with the background to start conducting original research in computer systems security. Core concepts such as basic security goals, threat models, notion of TCB and security policies vs. mechanisms. Operating system primitives for protection, reference monitors, authentication, and authorization. Examples of classic security policies from the literature (e.g., Biba, BLP) and their realization on modern systems. Various forms of hijacking attacks, such as buffer overflows, return-oriented programming, and non-control data attacks, and examples of such attacks as used by exploits in the wild. Design and implementation of defenses such as control-flow integrity, ASLR, privilege separation, capabilities,information-flow control and virtual machine introspection. Attacks and defenses against the Web ecosystem, mobile devices and the cloud platform.Emerging role of modern hardware in improving systems security. Other assorted topics based on current research literature. References: Security Engineering, 2nd Edition, Wiley, by Ross Anderson. http:// www.cl.cam.ac. uk/~rja14/book.html (free online copy) Research papers from systems security conferences and journals.

Vinod Ganapathy

Pre-requistes : None

References : None

E0 271 (AUG) 3 : 1

Graphics and Visualization

Graphics pipeline; transformations; viewing; lighting and shading; texture mapping; modeling; geometry processing - meshing, multi- resolution methods,geometric data structures; visualization - visualization pipeline, data reconstruction, isosurfaces,volume rendering, flow visualization.

Vijay Natarajan

Pre-requistes : None

References : Edward S. Angel and Dave Shreiner. Interactive Computer Graphics: A Top-Down Approach with Shader-Based OpenGL. Pearson, 2011. Dave Shreiner, Graham Sellers, John Kessenich, and Bill Licea-Kane. OpenGL Programming Guide: The Official Guide to Learning OpenGL. Addison-Wesley, 2013.Recent Literature.

E0 334 (AUG) 3 : 1

Deep Learning for Natural Language Processing

Introduction, Multilayer Neural Networks, Back-propagation,Training Deep Networks; Simple word vector representations: word2vec,GloVe; sentence, paragraph and document representations. Recurrent Neural Networks; Convolutional Networks and Recursive Neural Networks; GRUs and LSTMs; building attention models; memory networks for language understanding. Design and Applications of Deep Nets to Language Modeling, parsing, sentiment analysis,machine translation etc.

Shirish Krishnaji Shevade

Pre-requistes : None

References :

E0 358 (AUG) 3 : 1

Advanced Techniques in Compilation and Programming for Parallel Architectures

Parallel architectures: a brief history, design, Auto-parallelization for multicores, GPUs, and distributed Memory clusters Lock-free and wait-free data structures/algorithms for parallel programming Study of existing languages and models for parallel and high performance programming; issues in design of new ones.

Uday Kumar Reddy B

Pre-requistes : None

References : Aho, Lam, Sethi, and Ullman, Compilers: Principles, Techniques, and Tools, 2nd edition~Herlihy and Shavit, The Art of MultiProcessor Programming ~Ananth Grama, Introduction to Parallel Computing ~List of research papers and other material which will be the primary reference material will be available on course web page.

E1 277 (JAN) 3 : 1

Reinforcement Learning

Introduction to reinforcement learning, introduction to stochastic dynamic programming, finite and infinite horizon models, the dynamic programming algorithm, infinite horizon discounted cost and average cost problems,numerical solution methodologies, full state representations, functionapproximation techniques, approximate dynamic programming, partially observable Markov decision processes, Q-learning, temporal difference learning, actor-critic algorithms.

Pre-requistes : None

References : References: D.P.Bertsekas and J.N.Tsitsiklis,Neuro-Dynamic Programming, Athena Scientific, 1996. R.S.Sutton and A.G.Barto, Reinforcement Learning: An Introduction, MIT Press, 1998. D.P.Bertsekas,Dynamic Programming and Optimal Control, Vol.I, Athena Scientific, 2005.

E0 207 (JAN) 3 : 1

Computational Topology: Theory and Applications

1. Introduction to topological data analysis via recent applications 2.Mathematical preliminaries from group theory and linear algebra: group homomorphism and isomorphism, quotient group, classification of finitely generated Abelian groups, linear transformations, matrix representations 3.Complexes: Clique, Delaunay, Cech, Rips, random complexes, algorithms for constructing complexes 4. Simplicial homology: chains, cycles, the boundary operator, the homology group, simplicial maps, Betti numbers, Euler-Poincare characteristic, nerve theorem, matrix reduction algorithms 5. Persistent Homology: filtrations, persistence diagrams, barcodes, spanning acycles,algorithms 6. Morse functions: Morse Lemma, Morse-Smale complex, contour tree,Reeb graph, algorithms for construction and simplification, hierarchical representation 7. Random topology: Random complexes, Morse inequalities,Limiting distribution of Betti numbers and persistence diagrams 8. Software:TDA on R, Gudhi, Ripser,Javaplex,

Pre-requistes : None

References : Edelsbrunner, Herbert, and John Harer. Computational topology: an introduction. American Mathematical Soc., 2010.~Hatcher, Allen. Algebraic topology., (2001). ~Current Literature

E0 213 (JAN) 3 : 0

Quantum Safe Cryptography

Introduction to cryptography and communication security; Symmetric Key and Asymmetric Key Cryptosystems for data encryption and authentication; Impact of Quantum Computing on currently deployed cryptosystems; Some candidate post-quantum public key encryption and digital signature schemes using Error Correcting Codes, Lattices, Isogeny over Elliptic Curves, Multivariate-polynomials over finite fields, Cryptographic Hash Functions; Protocols for quantum-safe secure communication.

Pre-requistes :

References : (1) Bernstein D.J., Buchmann J. and Dahmen E. (Eds.): Post-Quantum Cryptography, Springer, 2010. (2) Galbraith S.D., Mathematics of Public Key Cryptography, Cambridge University Press, 2012. (3) Menezes A.J., van Oorshot P.C. and Vanstone S.A., Handbook of Applied Cryptography, CRC Press, 1996. (4)Recent research papers in the relevant areas.

E0 214 (AUG) 3 : 0

Applied Linear Algebra and Optimization

Linear Transformations and Linear Systems, Eigenvalues and Eigenvectors, Matrix Decompositions, Approximations and Completion with applications in Machine Learning and Recommender Systems. Optimization Basics- Gradient based methods, Coordinate descent methods, Newton Methods. Constrained optimization, Duality, and Applications in Machine Learning. Non-convex optimization for Machine Learning - Stochastic Optimization, Projected Gradient Descent and Alternating Optimization.

Shirish Krishnaji Shevade

Pre-requistes : None

References : i) Charu C Aggarwal, Linear Algebra and Optimization for Machine Learning, Springer, 2020 ii) Recent Literature

E0 339 (AUG) 3 : 1

Advanced Reinforcement Learning

Module 1: Model-Based Reinforcement Learning
Markov Decision Processes (MDPs); value functions and Bellman equations; Bellman operators and contraction; Value Iteration; Policy Iteration; Conservative Policy Iteration; exact Policy Gradient methods.

Module 2: Model-Free Reinforcement Learning
DQN; REINFORCE; TRPO; PPO; SAC; empirical benchmarking using ARLBench; instability, failure modes, and hyperparameter sensitivity in deep RL.

Module 3: Reliable Reinforcement Learning
Reliable Policy Iteration (RPI); Conservative RPI (CRPI); reliable deep RL implementations and monotonic improvement principles.

Module 4: Alternative Formulations of Decision Making
Average-reward reinforcement learning; quasi-hyperbolic discounting; risk-sensitive reinforcement learning.

Module 5: Multi-Agent and Distributed Reinforcement Learning
Markov games; federated reinforcement learning; evolutionary reinforcement learning.

Module 6: End-to-End Decision Systems
Sequential Attention-based Sampling for Histopathological Analysis (SASHA); design and implementation of modern RL-enabled decision systems.

Gugan Chandrashekhar Mallika Thoppe

Pre-requisites :
Graduate-level probability (e.g., E0 232), linear algebra (e.g., E0 214/E0 226), and Foundations of Reinforcement Learning (e.g., E1 277)
References : 1. Sutton, R. S. and Barto, A. G., Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2018.

2. Bertsekas, D. P., Neuro-Dynamic Programming, Athena Scientific, 1996.

E0 211 (AUG) 3 : 1

Compilers and Runtime Systems for Modern Languages

Compilers and run time systems:

The Lox Language. Bytecode. A virtual machine. Lexical analysis / scanning. Compiling expressions. Types of values. Strings. Compiler and runtime support for the following Lox features: Global variables. Local variables. Control-flow constructs. Calls and functions. Closures. Garbage collection. Classes, objects, methods, inheritance, and superclasses.

Type systems:

Basic features of Rust. Rust's type system, and how it manages the following features of Rust: Ownership of data. Memory allocation in the heap. Copy semantics and move semantics. Compiler-managed automated memory de-allocation. Immutable references, mutable references. Borrowing of permissions by references. Lifetimes of references. Lifetime annotations. Polymorphic type systems.

Raghavan K V

Pre-requisites :
Familiarity with C programming, and knowledge of basic data structures.
References : 1. “Crafting interpreters” book by Robert Nystrom. https://craftinginterpreters.com/
2. “Rust by Example”. https://doc.rust-lang.org/rust-by-example/index.html
3. “The Rust Programming Language” book. We will be using an experimental fork of this book created by researchers at Brown University.

E1 276 (AUG) 3 : 0

Foundations of Asymptotic Probability

Syllabus:

Weak convergence in metric spaces, tightness and relative compactness, the space C[0,1],Invariance principle and Donsker's theorem, conditional expectations, martingales, Doob's decomposition, Doob's maximal inequalities, martingale convergence theorems, Doob-Meyer decomposition, square integrable martingales, change of measure, large deviation principle, rate function, Cramer's theorem, Sanov's theorem, Fenchel-Legendre transform, Varadhan's lemma.

Shalabh Bhatnagar

Pre-requistes :
A basic course in probability theory (mandatory)
A course in measure
References : 1. Billingsley, P. (1999). Convergence of Probability Measures (2nd ed.). Wiley.
2. Shiryaev, A. N. (2019). Probability-2 (3rd ed.). Springer.
3. Borkar, V.S. (1994). Probability Theory: An Advanced Course. Springer.

E0 341 (AUG) 3 : 1

Topics in Combinatorial Optimization

This topics course will develop foundations and algorithmic techniques used to design and analyze efficient algorithms for optimization problems on graphs, networks, matroids, and other discrete structures. Emphasis will be placed on packing and covering problems along with discrete fair division problems. The course will address both recent algorithmic developments in these areas and connections with classic results. Among the algorithmic techniques and themes in packing and covering problems, the course will cover the following topics:
• Rounding and Weight Functions.
• Online Algorithms for Bin Packing and Lower Bounds.
• Configuration Linear Programs and Iterative Rounding.
• Ellipsoid Algorithm and Separation Oracle.
• Discrepancy-Based Rounding.
• Geometric Bin Packing: Shelf-Packing Analysis and Duality-Based Analysis
• Probabilistic Analysis and Beyond-Worst Case: IID Models, Secretary Problems, Prophet Inequalities.
We will also delve into the following combinatorial results and their connections to discrete fair division:
• Hypergraph Matching: Haxell's Matching Theorem, Santa Claus Problem, and Erdős Matching Conjecture.
• Graph Coloring and Packing: Theorems of Hajnal and Szemerédi along with results of Sauer and Spencer.
• Graph Connectivity: Győri–Lovász Theorem.
• Equitability under Matroid Constraints.
• Applications of Sperner's Lemma, including equitable division under non-monotone set functions and Monsky's Theorem.

The course will include a significant project component. Through these projects, students will identify and explore open problems in the above-mentioned topics, thereby engaging with active research threads in these areas.

Siddharth Barman , Arindam Khan

Pre-requistes :

Students should have completed either Theorist's Toolkit (E0 206)
References : • B. Korte and J. Vygen, Combinatorial Optimization: Theory and Algorithms, Springer, 2012.
• Three-volume book by A. Schrijver, Combinatorial Optimization: Polyhedra and Efficiency, Springer-Verlag, 2003.
• Williamson, David P., and David B. Shmoys. The Design of Approximation Algorithms. Cambridge University Press, 2011.

Electrical Communication Engineering

Preface

M.Tech (Electronics & Communication) - Program Requirements

OVERALL STRUCTURE: The programme requires 36 credits of coursework and 28 credits of project work.

The coursework requirements in the program include three compulsory core courses and at least one course from each of the three broad groups of courses listed below.

Program Core (9 credits)
E2 202 Random Processes (3:0)
E2 211 Digital Communication (3:0)
E2 285 MTech ECE Laboratory Course (1:2)

Group A (Communication & Networks)
(at least 3 credits)
E2 201 Information Theory (3:0)
E2 203 Wireless Communication (3:0)
E2 204 Stochastic Processes and Queuing Theory (3:0)
E2 205 Error-Control Coding (3:0)
E2 221 Communication Networks (3:0)
E2 241 Wireless Networks (3:0)
E2 242 Multiuser Detection (3:0)
E2 251 Communication Systems Design (3:0)

Group B (Signal & Information Sciences)
(at least 3 credits)
E0 259 Data Analytics (3:1)
E1 244 Detection and Estimation Theory (3:0)
E1 245 Online Prediction and Learning (3:0)
E2 212 Matrix Theory (3:0)
E2 236 Foundations of Machine Learning (3:1)
E9 203 Compressed Sensing and Sparse Signal Processing (3:0)
E9 211 Adaptive Signal Processing (3:0)
E9 231 MIMO Signal Processing (3:0)
E9 241 Digital Image Processing (2:1)

Group C (High Frequency Circuits & Systems)
(at least 3 credits)
E3 220 Foundations of Nanoelectronic Devices (3:0)
E3 237 Integrated Circuits for Wireless Communication (3:0)
E3 277 Introduction to Integrated Circuit Design (2:1)
E7 211 Photonics Integrated Circuits (2:1)
E7 221 Fiber-Optic Communication (2:1)
E8 204 Antenna Theory and Practice (3:0)
E8 242 Radio Frequency Integrated Circuits and Systems (2:1)
E8 262 CAD for High-Speed Chip Package Systems (3:0)

Electives: balance to meet a minimum of 36 course credits

Project (MTech Electronics and Communication) EX 299 (0:28)

E2 202 (AUG) 3 : 0

Random Processes

The axioms of probability theory, continuity of probability, independence and conditional probability. Random variables and their distribution, functions of a random variable, expectation. Jointly distributed random variables, conditional distribution and expectation, Gaussian random vectors. Convergence of sequences of random variables, Borel-Cantelli Lemma, laws of large numbers and central limit theorem for sequences of independent random variables, Markov inequality. Definition of a random process, stationarity. Correlation functions of random processes in linear systems, power spectral density. Discrete time Markov chains, recurrence analysis, Foster's theorem. The Poisson process.

Rajesh Sundaresan

Pre-requistes : None

References : A. Kumar, Discrete Event Stochastic Processes: Lecture Notes for an Engineering Curriculum. Online book.

E2 205 (AUG) 3 : 0

Error-Control Coding

Basics of binary block codes; mathematical preliminaries: groups, rings,fields and vector spaces; convolutional codes and the Viterbi algorithm;belief propagation with application to the decoding of codes; LDPC codes;finite fields, Reed-Solomon and BCH codes.

Navin Kashyap

Pre-requistes : None

References : R.M. Roth, Introduction to Coding Theory, Cambridge University Press,2006~T. Richardson and R. Urbanke, Modern Coding Theory

E2 207 (AUG) 3 : 0

Concentration Inequalities

Chandra R Murthy , Aditya Gopalan

Pre-requistes : None

References : None

E2 211 (AUG) 3 : 0

Digital Communication

Representation of signals and systems; Digital modulation techniques and their performance in AWGN channel; optimum receiver structures for AWGN channel;signal design for band-limited and power-limited channels; power and bandwidth efficiency tradeoff; coding and coded modulation techniques – capacity approaching schemes; ISI and equalization; Multichannel and multicarrier systems; Digital communications through fading multipath channels.

Sundar Rajan B

Pre-requistes : None

References : S. Haykin, Digital Communication, Wiley, 1999~J.G. Proakis,Digital Communication, 4th edition

E2 212 (AUG) 3 : 0

Matrix Theory

Vectors, vector norms, vector algebra, subspaces, basis vectors, Gramm-Schmidt orthonormalization. Matrices, matrix rank, matrix norms,determinant, inverse,condition number. Hermitian and symmetric matrices,positive definite matrices, unitary matrices, projection matrices and other special matrices. LDU decomposition, QR decomposition, eigenvalue decomposition, singular value decomposition. Solving linear system of equations using Matrices. Least-squares approach, total least squares approach. Numerical issues. Perturbation theory of matrices.Differentiation of scalar functions of vectors and matrices. Matrix functions of scalar variables, Kronecker product of matrices.Positive matrices, nonnegative matrices, stochastic matrices and Markov chains.

Sudhan Majhi

Pre-requistes :

References : References: Carl D Meyer, Matrix Analysis and Applied Linear Algebra,SIAM Publication, 2000 Theodore Shifrin and Malcolm Ritchie Adams,Linear Algebra: A Geometric Approach, W H Freeman and Comapany, Second Edition, 2011,Gilbert Strang, Linear Algebra and its Applications,Fourth Edition, Thomson Brooks/Cole, 2007. Horn, and Johnson, Matrix Analysis, Second Edition, Cambridge

E2 221 (AUG) 3 : 0

Communication Networks

Introduction to networking. TCP and UDP, TCP analysis. IP,optimal routing,algorithms for shortest path routing, routing protocols, Mobile IP. ARQ schemes and analysis, random access,random/slotted ALOHA, splitting algorithms, CSMA-CD, wireless LANs CSMA/CA, IEEE 802.11 MAC. Modelling and performance analysis in networks; deterministic analysis, scheduling;stochastic analysis - traffic models, performance measures, Little's Theorem,M/G/1 model,Priority queueing.

Chandramani Kishore Singh , Parimal Parag

Pre-requistes : None

References : A. Kumar, D. Manjunath, and J. Kuri, Communication Networking: An Analytical Approach, Morgan Kaufman Publishers, 2004.~D. Bertsekas and R. Gallager, Data Networks, 2nd Edition, Prentice-Hall India, 2002.~J.F. Kurose and K. W. Ross,Computer Networking: A Top-Down Approach Featuring the Internet, Pearson Education Asia, 2001.

E3 220 (AUG) 3 : 0

Foundations of Nanoelectronic Devices

Mathematical foundations of quantum mechanics, operators, bra and ket algebra, time independent and time dependent Schrodinger equation, crystal lattice and Brillouin zone, Bloch theorem, band theory of solids, tight binding, band structure examples (Si, Ge, III-V) in E-k space, effective mass, principles of operation of p-n junction (homo and hetero junction) and MOSFET, single gate versus multiple gates, bound states, effect of confinement, subbands, quantum capacitance, strain effects, tunneling, tunnel diode, intra-band and band to band tunneling in MOSFET, quantum theory of linear harmonic oscillators,phonons in solids, carrier mobility in MOSFET, quantum theory of angular momentum, electron spin.

Akshay Kumar Mahadev Arabhavi

Pre-requistes : None

References : D. J. Griffiths, Introduction of Quantum Mechanics, Prentice Hall.,A. Ghatak and S. Lokanathan, Quantum Mechanics, Trinity Press.,V. K. Thankappan, Quantum Mechanics, New Age. Solid State Physics, N. W. Ashcroft and N. D. Mermin.,S. M. Sze, Physics of Semiconductor devices, Wiley-Interscience.,Y. Taur and T. H. Ning, Fundamentals of modern VLSI devices, Cambridge University

E7 211 (AUG) 3 : 0

Photonics Integrated Circuits

Principles: Introduction to Photonics; optical waveguide theory; numerical techniques and simulation tools; photonic waveguide components – couplers,tapers, bends, gratings; electro-optic, acousto-optic, magneto-optic and non-linear optic effects; modulators, switches, polarizers, filters, resonators,optoelectronics integrated circuits; amplifiers, mux/demux, transmit receive modules; Technology: materials – glass, lithium niobate, silicon, compound semiconductors, polymers; fabrication – lithography, ion-exchange, deposition,diffusion; process and device characterization; packaging and environmental issues; Applications: photonic switch matrices; planar lightwave circuits,delay line circuits for antenna arrays, circuits for smart optical sensors;optical signal processing and computing; micro-opto-electro-mechanical systems; photonic bandgap structures; VLSI photonics

Srinivas Talabattula

Pre-requistes : None

References :
1) C. R. Pollock and M. Lip Son, Integrated Photonics, Kluwer Pub., 2003. 2) T. Tamir, (ed), Guided-wave optoelectronics, (2nd edition),

E8 311 (AUG) 2 : 1

Advanced Topics in Electromagnetics

Vinoy K J

Pre-requistes : None

References : None

E8 304 (AUG) 3 : 0

Electromagnetic Metamaterials: Concepts and Applications

• Background: General Historical perspective and idea of Metamaterials (MTMs), Dispersive model for the dielectric permittivity, Phase velocity and group velocity, Metamaterials and homogenization procedure, Metals and plasmons at optical frequencies, Wire mesh structures as low frequency plasmas, Diamagnetism in a stack of metallic cylinders, Split-ring resonator media, Media with negative permittivity and permeability: theory and properties, Origins of negative refraction and other properties. • Spatial Metamaterials: Transmission Line Realization (Brillouin's work), Ideal Homogeneous CRLH TLs (Composite Right-Left Handed Transmission Lines), LC Network Implementation and distributed 1D CRLH Structures,Conversion from Transmission Line to constitutive Parameters, Eigenvalue Problem for 2D MTMs. • Applications of Metamaterials: A.Microwave: Dual-band and enhanced band guided wave components,Negative and Zeroth-Order Resonators, Backfire-to-Endfire (BE)Leaky-Wave (LW) Antennas

Debdeep Sarkar

Pre-requistes :

References : 1. D. K. Cheng, Field and Wave Electromagnetics, Pearson Education Asia Ltd, Second Edition, 2006. 2. S. A. Ramakrishna and T.M.Grzegorczyk, Physics and Applications of Negative Refractive Index Materials, CRC Press, Taylor & Francis Group and SPIE Press,2009. 3. G. V. Eleftheriades and K. G. Balmain, Negative Refraction Metamaterials: Fundamental Principles and Applications

E3 277 (AUG) 2 : 1

Introduction to Integrated Circuit (IC) Design

1. Devices: Review of Device Characteristics, DC and Small Signal MOS I/V Characteristics, Short-channel effects and device models used in IC design, CMOS Processing and Layout. 2. Analog Circuits: CMOS CS/CG/CD Amplifiers, Cascodes, Current Mirrors, Differential Pairs. 3.Digital Circuits: MOS inverters: Static and Switching Characteristics, Combinational and Sequential MOS Logic Circuits, Low power CMOS logic circuits. 4.Important Design Concepts: Frequency Response, Noise, Feedback, Nonlinearity. 5.Larger Circuits and Sub-systems: Basic operational amplifier design, Stability and Compensation, OTAs. This course will provide hands-on exposure to industry standard VLSI design tools

Gaurab Banerjee

Pre-requistes :

References : 1. CMOS Digital Integrated Circuits, Analysis and Design, Kan,Leblebici, Kim, McGraw Hill Education, 4th edition. 2. Analysisand Design of Analog Integrated Circuits, Gray, Hurst, Lewis, Meyer, Wiley, 5th edition. 3. Design of Analog CMOS Integrated Circuits, Razavi, McGraw Hill Education, 2nd edition.

E9 333 (AUG) 3 : 1

Advanced Deep Representation Learning

Reference Material: 1.Understanding Machine Learning: From Theory to Algorithms, Shai Shalev-Shwartz and Shai Ben-David,Cambridge University Press 2. Murphy,Kevin P.Probabilistic Machine Learning: Advanced Topics, MIT Press, 2023 3. Goodfellow, Ian, Yoshua Bengio,and Aaron Courville. Deep learning, MIT Press,2016. 4. Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. Mathematics For Machine Learning. Cambridge University Press, 2020. 5. Machine Learning from Weak Supervision: An Empirical Risk Minimization Approach, By Masashi Sugiyama, Han Bao, Takashi Ishida, Nan Lu, Tomoya Sakai and Gang Niu, MIT Press 6. Deep Generative Modeling, Jakub M. Tomczak,Springer 2022 7. Semi-Supervised Learning, Olivier Chapelle, Bernhard Schölkopf and Alexander Zien, MIT Press 8. Seminal and Survey papers from Machine Learning Conferences such as ICML,Neurips, ICLR, CVPR, AISTATS etc

Prathosh A P

Pre-requistes :
1. A course on probability theory 2. A course on classical machine learning fundamentals 3. Moderate programming skills in Python
References : Recap on Fundamentals of Deep Learning: Empirical Risk Minimization, Divergence minimizations and Likelihood maximization Techniques, Deep Learning Architectures (Convolutional and Recurrent Architectures). Deep Generative Models: Introduction to Generative models, Autoregressive and invertible models, Latent variable models, Variational inference and recognition networks

E2 237 (AUG) 3 : 0

Statistical Learning Theory

The course provides statistical guarantees on the performance of various machine learning algorithms such as classification and regression. The upper bounds are derived from Radmacher complexity and VC dimensions and the lower bounds are derived from the information theoretic methods. We also derive high dimensional asymptotics relating decision theory to statistical physics methods. Course contents: 1.Bias complexity trade off, Rademacher complexity, VC-dimension 2.Multiclass classification, decision trees, nearest neighbours 3.Parameter estimation and nonparametric regression 4.Stochastic gradient descent 5.Statistical decision theory 6.Large-sample asymptotics 7.Mutual information method and lower bound via hypothesis testing 8.Entropic bounds for statistical estimation 9.Strong data processing inequalit

Parimal Parag

Pre-requistes :

First graduate course in probability theory or equivalent,
References : 1. Yury Polyanskiy and Yihong Wu, "Information Theory: From Coding to Learning", Cambridge University Press, forthcoming. 2.Yihong Wu, "Information-theoretic Methods for High-dimensional Statistics", lecture notes. http://www.stat.yale.edu/~yw562/teaching/it-stats.pdf 3.Martin Wainwright, "High-Dimensional Statistics", Cambridge University Press, 2019. 4.Mehryar Mohri, Afshin

E9 247 (AUG) 3 : 1

Learning for 3D Vision and Inverse Graphics

Camera geometry, structure from motion, image based rendering for novel view synthesis, neural radiance fields (NeRFs), plenoxels and other grid based methods, 3D Gaussian splatting, sparse input novel view synthesis, deep depth priors, plane sweep volume, dynamic radiance fields, optical flow and motion priors, generalizable radiance fields, camera pose optimization.

Rajiv Soundararajan

Pre-requistes :

Deep learning and either image processing or computer vision

References : 1. David A. Forsyth and Jean Ponce, Computer Vision: A Modern Approach, Pearson Education, 2003, 2. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010, 3. Recent papers

E1 240 (AUG) 3 : 0

Theory of Multi-Armed Bandits

This course introduces the theory and algorithms underlying the multi-armed bandit (MAB) problem in various settings, along with the fundamental limits of the framework (lower bounds). The first part focuses on regret minimization in stochastic MABs, covering algorithms such as UCB, KL-UCB, IMED, and Thompson Sampling, and their regret analysis, modern design principles like Information-Directed Sampling and the Decision Estimation Coefficient, and lower bound techniques using both classical change-of-measure arguments and modern information-theoretic tools. We will also study non-stationary MABs (e.g., sliding window methods and piecewise-stationary models) and rotting/blocking bandits with monotonic reward structures.

The second part of the course focuses on sequential active hypothesis testing, which includes the best-arm identification (BAI) setting of MAB as a special case. Topics include Wald's power-one sequential testing framework, along with modern lower bounds and sample complexity analysis for optimal algorithms in point-vs-point, composite-vs-point, and composite-vs-composite settings. We will then cover the classical BAI problem under fixed-confidence and fixed-budget settings, including state-of-the-art lower bounds, impossibility results, and algorithms such as LUCB, Track-and-Stop, and Bayesian approaches like top-two sampling and its connection to Thompson Sampling. We will cover connections between BAI and Wald's testing framework, the gamification approach to BAI, and BAI with multiple correct answers, and epsilon-BAI. We will also explore linear bandits and optimal experimental design principles, including algorithms such as LinUCB, GLMs, epoch-greedy, and logistic models, along with A-, D-, and G-optimality criteria.

In the final part of the course, we will study generalizations such as dueling bandits (e.g., Relative UCB), stochastic partial monitoring (an application of the Information-Directed Sampling principle), and restless bandits (a generalization of MABs with time-evolving arms, where index-based policies such as the Whittle and Gittins indices are employed).

Shubhada Agrawal

Pre-requistes :

1. A course on probability theory or random processes.

References :

1. Introduction to Multi-Armed Bandits by Aleksandrs Slivkins
2. Bandit Algorithms by Tor Lattimore and Csaba Szepesvári
3. Multi-Armed Bandit Allocation Indices by John C. Gittins, Kevin D. Glazebrook, and Richard Weber

EX 299A (AUG) 0 : 8

Project (MTech Electronics and Commun, Aug term)

MTech project - mandatory for all MTech (Electronics & Communication Engg) students.

Navin Kashyap

Pre-requistes : None

References : Not applicable

E2 252 (AUG) 3 : 0

Communication and Radar Systems Design

• Communication link design for AWGN channels; path loss models, noise figure, receiver sensitivity, pink noise, link budget for deep space communication - a case study.

• Communication subsystem requirements/specifications and impairments modeling: analog front-end, up/down conversion architectures, oscillator phase noise, sampling jitter, IQ imbalance, carrier frequency offset (CFO), sampling frequency offset (SFO), error vector magnitude (EVM), DAC/ADC interface, quantization noise and clipping, dynamic range, ADC noise floor, non-linearities: 1 dB compression point, IIPn, power amplifier (PA) non-linearities, AM/AM, AM/PM.

• Compensation techniques: Tx/Rx IQ imbalance estimation and compensation, effect of CFO in OFDM, CFO estimation and compensation in OFDM, SFO estimation and correction in OFDM.

• Introduction to radar sensing principles, signals, and systems; radar waveforms, ambiguity functions - self-ambiguity, cross-ambiguity, delay/Doppler resolution; integrated sensing and communication (ISAC).

Chockalingam A , Nishant Mehrotra

Pre-requistes : None

References : 1. RF Analog Impairments Modeling for Communication Systems Simulation: Application to OFDM-based Transceivers by Lydi Smaini, John-Wiley & Sons, 2012.

E7 225 (AUG) 3 : 1

Basics of Optics and Photonics

Course Description: This course introduces the fundamental principles of optics and photonics through a balanced combination of theory, numerical simulations, and laboratory demonstrations. Topics include geometrical optics, optical wave propagation, interference, diffraction, polarization, Fourier optics, optical imaging, and key photonic devices such as lasers, optical fibers, and photodetectors, with examples from modern optical systems including communication, imaging, sensing, and spectroscopy. The course provides a strong foundation for students interested in pursuing advanced courses and research in photonics, optical engineering, imaging, optical communication, lasers, and related interdisciplinary areas.

Varun Raghunathan , Balaswamy Velpula

Pre-requistes : None

References : Textbooks/References
1. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich (latest Edition)
2. Photonic Devices: Jia Ming Liu (latest Edition)

Electrical Engineering

Preface

E0 330 (JAN) 3 : 1

Convex Optimization and Applications

Pre-requistes : None

References : None

E1 251 (AUG) 3 : 0

Linear and Nonlinear Optimization

Necessary and sufficient conditions for optima; convex analysis; unconstrained optimization; descent methods; steepest descent, Newton's method, quasi Newton methods, conjugate direction methods; constrained optimization; Kuhn-Tucker conditions, quadratic programming problems; algorithms for constrained optimization;gradient projection method, penalty and barrier function methods,linear programming, simplex methods; duality in optimization, duals of linear and quadratic programming problems

Muthuvel Arigovindan

Pre-requistes : None

References : References: Luenberger D G,Introduction to Linear and Nonlinear Programming, 2nd edition,Addison Wesley,1984.

E9 201 (AUG) 3 : 0

Digital Signal Processing

Discrete-time signals and systems, frequency response, group delay,z-transform, convolution, discrete Fourier transform (DFT), fast Fourier transform (FFT) algorithms, discrete Cosine transform (DCT), discrete Sine transform (DST), relationship between DFT, DCT, and DST; design of FIR and IIR filters, finite word length effects, Hilbert transform,Hilbert transform relations for causal signals, Karhunen-Loève transform. Introduction to linear prediction,bandpass sampling theorem,bandpass signal representation.

Soma Biswas , Prasanta Kumar Ghosh

Pre-requistes : None

References : References:,Proakis and Manolakis, Digital Signal Processing, Prentice HallIndia,.,Oppenheim A V , Schafer R W,Discrete-time Signal Processing, Prentice Hall, 1998.,Sanjit K Mitra,Digital Signal processing : A Computer Based Approach, Tata McGraw-Hill

E1 222 (AUG) 3 : 0

Stochastic Models and Applications

Probability spaces, conditional probability, independence,random variables,distribution functions, multiple random variables and joint distributions,moments, characteristic functions and moment generating functions, conditional expectation, sequence of random variables and convergence concepts, law of large numbers, central limit theorem, stochastic processes, Markov chains,Poisson process.

Subbayya Sastry P

Pre-requistes : None

References : References: Ross S M,Introduction to Probability Models,(6th Edition),academic Press and Hardcourt Asia,2000.

E1 241 (AUG) 3 : 0

Dynamics of Linear Systems

Background material on matrix algebra, differential equations. Representation of dynamic systems, equilibrium points and linearization. Natural and forced response of state equations, state space descriptions, canonical realizations. Observability and controllability, minimal realization. Linear state variable feedback,stabilization, modal controllability, Jordan form, functions of matrices, pole- placement, Lyapunov matrix equations. Asymptotic observers, compensator design, and separation principle. Preliminary quadratic regulator theory.

Kiran Kumari

Pre-requistes : None

References : Joao P. Hespanha, “Linear systems theory”, Princeton University Press,2009;Panos J. Antsaklis, Anthony N. Mitchel, "Linear Systems",Birkhauser, 1997;Chi-Tsong Chen, “Linear System Theory and Design”,Oxford University Press;Thomas Kailath, “Linear Systems”, Pearson, 2016 reprint of 1980 edition; Gilbert Strang, “Linear algebra and its applications”

E4 231 (AUG) 3 : 0

Power System Dynamics and Control

Introduction to system dynamics, concepts of stability, modeling of generator,transmission networks, loads and control equipment, small signal stability-lowfrequency oscillations – methods of analysis for single and multi-machine systems, power system stabilizers.

Gurunath Gurrala

Pre-requistes : None

References : References: Padiyar K R,Power System Dynamics,Stability and Control,Interline Publishing,1996.

E4 234 (AUG) 3 : 0

Advanced Power Systems Analysis

Introduction to Power System Analysis; Admittance Model of Power System Elements; Kron's Reduction; Power Flow Analysis: Gauss–Seidel, Newton Raphson,Fast Decoupled; Programming Consideration for Large Systems; Balanced and Unbalanced Radial Power Flow, AC-DC Power Flow, Harmonic Power Flow, Continuation Power Flow; Steady-State Voltage Stability; Power Flow Tracing;Loss Allocation Methods; Network Congestions; Available Transfer Capability;Contingency Analysis; Z-Bus Formulations; Fault Analysis using Z-Bus;Structure of Indian Power Systems; Indian Electricity Grid Code.

Sarasij Das

Pre-requistes : None

References : References: Kusic G L, Computer Aided Power System Analysis, CRC Press, 2nd edition, 2009.,Arilaga J, and Watson N R, Computer Modelling of Electrical Power Systems, Wiley, 2005.,Grainger J J, and Stevenson W D, Power System Analysis, McGraw Hill Education (India) Pvt Ltd.,2003.,Wang X,Song Y and Irving M, Modern Power Systems Analysis,Springer, 2008, Arilaga J, and Watson N

E6 201 (AUG) 3 : 1

Power Electronics

Power switching devices: diode, BJT. MOSFET, IGBT; internal structure, modeling parameters, forward characteristics and switching characteristics of power devices; control and protection of power switching devices; electromagnetic elements and their design; choppers for dc to dc power conversion; single and multi-quadrant operation of choppers; chopper controlled dc drives; closed loop control of dc drives. Hands-on exercises:soldering and desoldering practice, pulse generator circuit, inductor design and fabrication,thermal resistance of heat sink, switching characteristics of MOSFET,dc-dc buck converter, CCM and DCM operation, linear power supply,output voltage feedback for over current protection, dc-dc boost converter,measurement of small- signal transfer functions,closed loop control of boost converter.

Vishnu Mahadeva Iyer

Pre-requistes : None

References : Mohan N, Power Electronics; Principles, Analysis and Design, John Wiley, 1989.,Robert Ericson, Fundamentals of Power Electronics, Chapman & Hall, 1997,Umanand L, Power Electronics:Essentials and Applications, Wiley India,2009,Baliga B J, Power Semiconductor Devices, PWS Publishing Company, 1996,Sorab K.Ghandhi, Semiconductor Power Devices, John Wiley and Sons,

E6 223 (AUG) 3 : 0

PWM Converters and Applications

AC/DC and DC/AC power conversion. Overview of applications of voltage source converters, pulse modulation techniques for 1-phase and 3-phase bridges; bus clamping PWM, space vector based PWM, advanced PWM techniques, practical devices in converter. Calculation of switching and conduction losses.Compensation for dead time and DC voltage regulation; dynamic model of a PWM converter, multilevel converters; constant V/F induction motor drives;estimation of current ripple and torque ripple in inverter fed drives. Line-side converters with power factor compensation.

Narayanan G

Pre-requistes : None

References : References: Mohan, Undeland and Robbins; Power Electronics; Converters, Applications and Design, John Wiley and Sons, 1989.,Erickson R W, Fundamentals of Power Electronics, Chapman and Hall, 1997.,Vithyathil J, Power Electronics:Principles and Applications; McGraw Hill, 1995. Current Literature.

E6 224 (AUG) 3 : 0

Topics in Power Electronics and Distributed Generation

Introduction to distribution systems, fault calculations, fault contribution and protection coordination with Distributed Generation (DG), intentional and unintentional islanding, impact on distribution system voltage profile,relaying requirements for DG systems. Power converters for grid interconnection and micro-source-side power converter topologies, inverter modeling, component selection, design for efficiency and reliability,grounding and filtering requirements. Power converter design trade-off considering efficiency and reliability. Control requirements for DG,phase locking, current control, DC bus control, power quality,unbalance, harmonics,surges, voltage and frequency windows.

Vinod John

Pre-requistes : None

References : V. Ramanarayanan, Switched Mode Power Conversion, 2010.~Arthur R, Bergen,Vittal, Power Systems Analysis (2nd Ed) Prentice Hall, 1999. ~Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics:Converters,Applications and Design; Wiley 2002.~IEEE papers and standards, datasheets,current literature.

E6 225 (AUG) 3 : 0

Advanced Power Electronics

Rectifiers: Line commutated, unidirectional power factor correction (PFC), bi-directional, rectifiers with isolation. AC to AC power converters: Matrix converters, Multistage conversion: voltage link and current link topology,High frequency link converters. DC to DC converters: Dual active bridge,Resonant converters. Inverters: Multilevel, Inverters for open ended load configurations, Resonant inverters. High frequency magnetics: Modeling and loss estimation, Inductor and transformer design. Thermal design. Emerging power semi-conductor devices.

Kaushik Basu

Pre-requistes : None

References : Ned Mohan, Tore M Undeland, William P Robbins, Power Electronics: Converters,Applications and Design, Wiley, Third Edition 2007.,Erickson R W and Maksimovic D, Fundamentals of Power Electronics, Springer, Second Edition 2005.,Umanand L, Power Electronics and Essentials, Wiley, 2009.,Ramanarayanan V,Switched Mode Power Conversion, Course Notes, IISc, 2004. Current

E8 201 (AUG) 3 : 0

Electromagnetism

Review of basic electrostatics, dielectrics and boundary conditions, systems of charges and conductors, Green’s reciprocation theorem, elastance and capacitance co-efficient, energy and forces,electric field due to steady currents, introduction to magnetostatics, vector potential, phenomena of induction, self and mutual inductance, time- varying fields, Maxwell’s equations.

Udaya Kumar

Pre-requistes : None

References : References:,Kraus J D, Electromagnetics, McGraw Hill International.,Jeans J H,The Mathematical Theory of Electricity and Magnetism, Cambridge University Press.,Smythe W R, Static and Dynamic Electricity, McGraw Hill Book Company,New York.

E9 241 (AUG) 2 : 1

Digital Image Processing

Image formation and representation, image histograms, binarization and thresholding, binary morphology, point operations, histogram equalization and matching, spatial filters, 2D Fourier transform, discrete space Fourier transform, discrete Fourier transform, sampling theorem, linear and circular convolution, Wiener filter for restoration, order statistic filters, bilateral filter, image downsampling and upsampling, edge detection, Hough transform,Haris corner detection, scale invariant feature transform, bag of words model,deep learning of image features.

Soma Biswas , Bharath V

Pre-requistes : None

References : R. C. Gonzalez and R. E. Woods , Digital image processing, Prentice Hall,2008~Richard Szeliski, Computer Vision: Algorithms and Applications, Springer,2010~A K Jain , Fundamentals of digital image processing, Prentice Hall,1989~A. C. Bovik, Al Bovik's Lecture Notes on Digital Image Processing, The University of Texas at Austin, 2019~David A. Forsyth and Jean Ponce, Computer

E0 298 (AUG) 3 : 1

Linear Algebra and Its Applications

[A] Theory: Solution of linear equations, vector space, linear transformations, matrix representation, inner products and norms, orthogonality, trace and determinant, eigenvalue decomposition,symmetric (Hermitian) matrices and quadratic forms, singular value decomposition. [B] Applications: linear regression and normal equation, linearly constrained optimization, optimal subspace and low-rank approximations, dynamical systems, Markov chains, closest orthogonal transform, graph Laplacian and connectivity

Vaibhav Katewa

Pre-requistes :

References : [1] S. Axler, Linear Algebra Done Right, Springer, 2015. [2] C. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2000.

E6 228 (AUG) 3 : 0

Grid Integration of Inverter-Based Energy Sources

Synchronous Generator operation, modeling and control, transient behavior modeling; short-circuit and symmetrical components. Three-phase two-level voltage source inverter (VSI), L-C-L filter design, sine and space vector PWM, common-mode voltage and current. Current-controlled grid following inverter, phase-locked loop (PLL), inverter modeling for current control; proportional-resonant controller, synchronous reference frame (d-q) control. Energy sources control, battery – P-Q control, PV – P-Q control, Active front end(AFE)–dc voltage and Q control; startup sequence and protection features of the inverter; LVRT and HVRT.Modeling of grid-connected inverter including PLL dynamics, Stability of operation at higher grid impedance. Voltage-controlled grid-forming model and control, voltage and frequency control; P-Q droop control. Utility-scale battery energy storage system (BESS), inertia and impedance of the power network; inertia emulation

Samir Hazra

Pre-requistes :

E6 201 Power Electronics or E6 202 Design of power converters or E3

References : (a) Grid Converters for Photovoltaic and Wind Power Systems, Remus Teodorescu; Marco Liserre; Pedro Rodriguez (b) Dynamics and Control of Electric Transmission and Microgrids, K. R. Padiyar, Anil M. Kulkarni

E1 250 (AUG) 3 : 0

Mathematics for Electric Power Engineers

Solving linear equations, row-reduced echelon form and Gauss elimination. Vector space, linear independence, basis, dimension, rank nullity theorem, orthogonality, the four fundamental subspaces, positive definiteness, singular value decomposition, pseudo inverse. Linear programming, simplex method, duality. Linear dynamical systems, eigen decomposition and Jordon form. Stability. Numerical solution of algebraic, root-finding algorithms such as Newton's method.Unconstrained nonlinear optimization, first and second-order necessary conditions, steepest descent, and Newton's algorithm. Constrained optimization, necessary conditions, Lagrange multipliers. Penalty, barrier, and constrained steepest descent algorithms. Sequential linear programming and quadratic programming. Nonlinear dynamical systems, existence and uniqueness of solutions, stability of equilibrium points-Lyapunov's method, gradient and Hamiltonian systems, limit cycles: Poincaré Bendixson theorem.Numerical solution of differential equations, Euler and Runge-Kutta methods.Accuracy, stability, and convergence time

Kaushik Basu

Pre-requistes :

BTech Engineering Mathematics.
References : 1.Linear Algebra and Its Applications by Gilbert Strang. 2.Applied Linear Algebra by Peter J Oliver and, Chehrzad Shakiban. 3.Linear and Nonlinear Programming by David G Luenberger and, Yinyu Ye. 4. Differential Equations, Dynamical Systems, and an Introduction to Chaos by Morris W. Hirsch, Stephen Smale and, Robert L. Devaney. 5. Introductory Methods of Numerical Analysis by SS

E6 240 (AUG) 3 : 0

Multilevel Inverters: Topology and Control

Motivation for MLIs, Voltage stress and waveform quality, Applications of MLIs; Basic Topologies: Neutral Point Clamped (NPC), Flying Capacitor (FC), Cascaded H-Bridge (CHB), Voltage level generation principles; Switching States and Operation Principles: Redundancies in MLIs, Symmetric vs Asymmetric MLIs; Modulation Techniques – I: Sinusoidal PWM (SPWM), Phase Disposition (PD), Phase Opposition (POD), Alternate Phase Opposition (APOD); Modulation Techniques – II: Space Vector PWM (SVPWM) for NPC and CHB, Harmonic performance analysis; Capacitor Voltage Balancing in FC and NPC: Active and passive balancing methods; Advanced MLI Topologies: Active NPC, T-Type, Packed U-Cell (PUC), Switched Capacitor MLIs (SCMLIs); Control Techniques: Open-loop control strategies, Carrier-based and reference-based control, Model Predictive Control; Fault Tolerance and Protection in MLIs: Fault types, detection and mitigation strategies; Industry Trends and Research Challenges: transformer-less MLI topologies for achieving compact and cost-effective designs, Analysis of Wide Band Gap devices (e.g., SiC, GaN) for high-efficiency MLI operation.

Tapas Roy

Pre-requistes :

Power Electronics (E6-201) or Equivalent
References : Text Books:
T1. "Multilevel Converters for Industrial Applications" by Sergio A. González, Santiago A. Verne, María I. Valla – Springer, 2014
T2. "Advanced DC/AC Inverters-Applications in Renewable Energy" by F. L. Luo and H. Ye, CRC Publications, 2017

E4 240 (AUG) 3 : 0

Robust Control Theory and Its Application

Module 1: Overview of classical control systems, concepts of controller design based on classical gain and phase margins, classical margins based on Nyquist plots, limitations of classical margins.
Module 2: Introduction of robust control theory, concept of norms of system, concepts of norm of signals, introducing H-infinity norm, Singular value decomposition, relation of H-infinity norm with singular values.
Module 3: Introducing uncertainty modelling, real-parametric uncertainty, complex uncertainty, LTI dynamic uncertainty, multiplicative and additive uncertainty, Upper and Lower Linear fraction transformation.
Module 4: Introducing mixed sensitivity synthesis, concepts of weighting transfer function, H-infinity loop-shaping design, and generic Delta-P-K framework development.
Module 5: Concept of robust stability, H-infinity sub-optimal problem formulation and solution methodology, introducing the structured singular value, concept of robust performance, concept of mu-synthesis problem and controller design.
Module 6: Concept of model order reduction methods, truncation and residualization, balanced realisations, balanced truncation and balanced residualization, optimal Hankel norm approximation.

Soham Chakraborty

Pre-requistes :
Undergraduate-level Control System Theory : Transfer functions, Bode plot, Root-locus method, Nyquist Theory, Negative feedback

References : [1] Skogestad, Sigurd, and Ian Postlethwaite. Multivariable feedback control: analysis and design. john Wiley & sons, 2005.
[2] MATLAB Robust Control Toolbox: Design robust controllers for uncertain plants.
[3] Gu, Da-Wei, Petko Hristov Petkov, and Mihail Mihaylov Konstantinov. Robust control design with MATLAB. London: Springer London, 2005.

Electronic Systems Engineering

Preface

E0 284 (AUG) 2 : 1

Digital VLSI Circuits

Introduction to MOS transistor theory, Circuit characterization & simulation,theory of logical effort, interconnect design and analysis combinationalcircuit design, sequential circuit design.Design methodology & tools, testing & verification, datapath subsystems, array subsystems, power and clock distribution, introduction to packaging.

Viveka Konandur Rajanna

Pre-requistes : None

References : N. Weste and D. Harris, CMOS VLSI Design. A Circuits and Systems Perspective,Addison Wesley, 2005~J. M. Rabaey, A. Chandrakasan, and B. Nikolic, Digital Integrated Circuits~Current literature

E3 245 (AUG) 2 : 1

Processor System Design

Introduction: Basic Processor Architecture, Instruction Set Design, Datapath and Controller, Timing, Pipelining. CISC Processor Design: Architecture,Design. RISC Processor Design: single cycle implementation, multi cycle implementation, pipelined implementation, exception and hazards handling, RISC-V. Memory Hierarchy: Cache, Paging, TLB. Bus: Bus Topologies, AXI, PCIe, Bus Bridges, BFM, Network-on-Chip. Superscalar Processors Design: Superscalar organization, superscalar pipeline overview, VLSI implementation of dynamic pipelines, register renaming, reservation station, reordering buffers, branch predictor, and dynamic instruction scheduler etc.

Kuruvilla Varghese

Pre-requistes : None

References : Computer Organization and Design: The Hardware/Software Interface, The Morgan Kaufmann, By David A. Patterson and John L. Hennessy~Computer Architecture: A Quantitative Approach, The Morgan Kaufmann By John L. Hennessy and David A.Patterson~Modern Processor Design: Fundamentals of Superscalar Processors,McGraw-Hill By John P. Shen ~Current Literature

E3 258 (AUG) 2 : 1

Design for Internet of Things

Introduction to IoT, Challenges in IoT - Power, Security, Identification, Location, Low Power Design, Energy harvesting systems, Power management algorithms, Working with ADC, DC-DC and LDO component datasheets, ARM processor low power features, multiprocessor systems, Lifetime estimation, RFID and its applications, Backscattering techniques, Working with protocols such as MQTT, COAP, for low power and energy harvesting sensor nodes, Low power wireless networks - Bluetooth Low Energy (BLE), and IEEE 802.15.4e TSCH. Low Power Wide Area Networks - LORA, NBIoT and power-saving modes, CAT-LTE-M1.

Prabhakar T V

Pre-requistes : None

References : RFCs, Application notes, Standards, Handbooks, Recent papers on selected topics.

E3 257 (AUG) 2 : 1

Embedded System Design

Development toolchain (Compiler, Linker and Debugger), ARM Cortex processor architecture, Memory subsystem, caching, interfacing and programming peripherals, GPIO, UART, I2C, SPI, interrupts and NVIC architecture, interrupt driven standalone system

Dagale Haresh Ramji

Pre-requistes : None

References : Definitive Guide to Cortex M3 Architecture,Joseph Yiu~Practical Microcontroller Engineering with ARM Technology,Ying Bai,Linkers & Loaders

E3 282 (AUG) 0 : 0

Basics of Semiconductor Devices and Technology

Introduction to semiconductor device physics: Review of quantum mechanics, electrons in periodic lattices, E-k diagrams, quasiparticles (electrons, holes and phonons) in semiconductors. Carrier statics and dynamics, carrier transport under low electric and magnetic fields: Mobility and diffusivity; Carrier statistics; Continuity equation, Poisson's equation and their solution. High field effects: Velocity saturation, hot carriers and avalanche breakdown. Semiconductor Junctions: Schottky, p-n junction and hetero-junctions and related physics. Ideal and nonideal MOS capacitor, band diagrams and CVs; Effects of oxide charges, defects and interface states; Characterization of MOS capacitors: HF and LF CVs. Physics of transistors

Maheswari Sivan

Pre-requistes : None

References : S. M. Sze,Physics of Semiconductor Devices,John Wiley,Donald Neamen, Semiconductor Physics and Devices

E6 203 (AUG) 1 : 2

Mechatronics System Design

Mechatronics intro, bond graph modelling of mechatronic systems, sensors and circuits - voltage, current, temperature, pressure, velocity, position, angular velocity, flow, flow rate, torque, stress, strain, etc., electrical actuators and drive - moving iron,solenoids, relays, electric motors, servo motor, stepper motor, motor selection, mechanical actuators - kinematic chains, cam, gears,ratchet, clutches, flexible elements, brakes etc., interfacing microcontrollers with actuators, control of actuators, robotic manipulator, differential dynamic mobile robot

L Umanand

Pre-requistes : None

References : 1.System dynamics: A unified approach, Dean Karnopp and Ronald Rosenberg, John Wiley and Sons 2.Mechatronics:Principles and Applications, Godfrey C Onwubolu, Elsevier publishers, 2005, 3.Digital control of dynamic systems, Franklin, Powell and Workman, Addison-Wesley, 3ed

E0 297 (AUG) 2 : 1

Cryptographic Hardware Accelerators

Introduction to Symmetric Key and Public Key Cryptography, Advanced Encryption Standard (AES), Secure Hash Algorithm (SHA), Light-Weight Cryptography, Multi-Precision Integer Modular Arithmetic, Rivest-Shamir-Adleman (RSA), Elliptic Curve Cryptography (ECC), Circuit-Algorithm-Architecture Co-Optimizations, Efficient Hardware Implementations, Timing and Power Side-Channel Analysis, Algorithm-Level and Architecture-Level Side-Channel Countermeasures

Utsav Banerjee

Pre-requistes :
E0 217 (Efficient and Secure Digital Circuits and Systems)

References : Journal Articles, Conference Papers, Preprints and Cryptography Standards

E2 240 (AUG) 3 : 0

Introduction to Machine Learning

AI and machine learning, Review of linear algebra, probability and convex optimization, Statistical learning framework, Linear regression, Classification, Kernel methods, Clustering, Gaussian mixture models, Expectation maximization, Dimensionality reduction, Probabilistic graphical models, Hidden Markov models, Markov decision processes, Q learning

Chandramani Kishore Singh

Pre-requistes :
Undergraduate level calculus, linear algebra, probability and optimization

References : 1.Shai Shalev-Shwartz, Shai Ben-David, Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press
2. Kevin Murphy, Probabilistic Machine Learning: An Introduction, MIT Press
3. Christopher Bishop, Pattern Recognition and Machine Learning, Springer

E3 229 (AUG) 3 : 0

Principles of Microelectronic Devices

This course offers an in-depth understanding of microelectronic device principles, with a focus on semiconductor physics, device structures, and transport phenomena. Additionally, the course utilises TCAD simulations to enhance learning, culminating in concepts such as scaling theory, small geometry effects, and performance boosting technologies, thereby equipping students with the critical knowledge necessary for applications in semiconductor technology. Modules 1–2: Energy bands, Fermi level, DOS, crystal/reciprocal lattices, doping, carriers, ionization and temperature effects. Module 3: Carrier transport, scattering, phonons, mobility, drift-diffusion equation, generation-recombination. Modules 4–7: P-N diodes, MOS capacitors and transistors, regimes of operation, small-signal and transient analysis and cryogenic behavior with TCAD. Modules 8–10: Scaling Theory, DIBL, leakage, hot carriers and advanced technologies: SOI, FinFETs, high-k metal gates, and strained Si.

Santanu Mahapatra

Pre-requistes :
Basics of quantum mechanics

References : 1. Fundamentals of Modern VLSI Devices by Yuan Taur and Tak H. Ning
2. Advanced Semiconductor Fundamentals by Robert Pierret

E3 293 (AUG) 3 : 0

Semiconductor Fabrication and VLSI Process Technol

Historical Perspective, CMOS Scaling and Technology Landscape: integrated circuits, planar process, MOS transistors, CMOS circuits, Moore's law, device scaling, roadmap thinking, CMOS, BiCMOS, BCD, FinFET-era technologies and emerging directions. Modern CMOS Technology and Device Structures: substrate selection, well formation, threshold implants, gate oxide, polysilicon/dummy-gate concepts, LDD, halo, source/drain doping, strain engineering, contacts, high-k/metal-gate and BEOL modules, and FinFET process integration. Semiconductor Materials, Crystal Growth and Wafer Preparation: crystal structures, defects, Czochralski and Float-Zone growth, dopant incorporation, compound-semiconductor growth, wafer slicing, polishing, SOI, bonded and epitaxial wafers. Cleanrooms, Wafer Cleaning, Gettering and Yield: contamination control, wafer cleaning, RCA clean, resist removal, gettering, lifetime control, yield modeling and process control. Lithography and Resist Processing: optical and e-beam lithography, resists, exposure systems, image formation, lift-off, OPC, phase-shift masks, computational lithography, multipatterning and nanoimprint. Semiconductor/Insulator Interfaces, Oxidation and High-k Gate Stacks: thermal oxidation, Deal-Grove model, Si/SiO2 interface defects, high-k dielectrics, metal gates and SiC oxidation. Diffusion, Annealing and Dopant Activation: Fick's laws, analytic and numerical diffusion models, segregation, vacancy/interstitial mechanisms and dopant activation. Ion Implantation and Implant Damage: implant profiles, stopping, channeling, SRIM analysis, damage annealing and transient enhanced diffusion. Etching, Wet Processing, Atomic Layer Etching and CMP: wet/dry etching, RIE, plasma chemistry, ALE and CMP. Thin-Film Deposition and Related Process Modules: CVD, PVD, ALD, MBE, epitaxy, silicidation, lift-off and electroplating. Back-End, Contacts, Interconnects and Advanced Packaging: contacts, silicides, Cu/low-k interconnects, electromigration, chiplets and 3D integration. Process Integration, Non-CMOS Flows and Process-Device Co-Design: CMOS, LDMOS/BCD, GaN, SiC and III-V process flows, reliability and co-design. Simulation and Practical Design Exercises: TCAD and SRIM-based process analysis.

Mayank Shrivastava

Pre-requistes : NIL

References : • J.D. Plummer, and P.G. Griffin, Integrated Circuit Fabrication – Science & Technology, 2024
• IEDM Papers and presentations on Advanced CMOS, Hi-K metal gate process, FinFETs, Nanosheet FETs, etc.
• S.M. Sze (Ed), VLSI Technology, 2nd Edition, McGraw Hill, 1988.

Division of Interdisciplinary Sciences

Preface

The Division of Interdisciplinary Research consists of the Centre for Biosystems Science & Engineering, Department of Computational and Data Sciences, Centre for Society and Polity, Interdisciplinary Centre for Energy Research, Interdisciplinary Centre for Water Research, Centre for Nano Science and Engineering, Centre for Infrastructure,Sustainable Transportation and Urban Planning, Department of Management Studies, Robert Bosch Centre for Cyber Physical Systems, Supercomputer Education and Research Centre and Interdisciplinary Mathematical Sciences. The courses offered in the different departments of the Division have been reorganized after review and revision, and have been grouped department wise. These are identified by the following codes.

BE Centre for Biosystems Science & Engineering

CP Robert Bosch Centre for Cyber Physical Systems

ER Interdisciplinary Centre for Energy Research

DS Department of Computational and Data Sciences

MG Department of Management Studies

MS Interdisciplinary Mathematical Sciences

NE Centre for Nano Science and Engineering

UP Centre for Infrastructure,Sustainable Transportation and Urban Planning

The first two digits of the course number have the departmental code as the prefix. The Departments/Centres of the Division provide facilities for research work leading to the degrees of M Tech,M Tech (Research)and PhD. There are specific requirements for completing a Research Training Programme for students registered for research at the Institute. For individual requirements, students are advised to consult the Departmental Curriculum Committee. The M Tech Degree Programmes are offered in Centre for Nano Science and Engineering, Department of Computational and Data Sciences and Robert Bosch Centre for Cyber Physical Systems. Department of Civil Engg and CiSTUP jointly offer an M Tech Programme in Transportation Engineering. Department of Management Studies offers a Master of ManagementProgramme. Most of the courses are offered by the faculty members of the Division, but in certain areas, instruction by specialists in the field and experts from industries are also arranged.

Prof. Navakanta Bhat

Dean

Division of Interdisciplinary Sciences

Society and Policy

Preface

Bioengineering

Preface

Educating a new breed of young researchers at the biology-engineering interface is the primary goal of the Interdisciplinary M. Tech and PhD Programme in Bioengineering. It is hoped that the students in this programme are at equal ease with a core area in biology and a core area in engineering.

August Semester Courses
BE 203 Bioengineering Practicum I 0:1
BE 204 Bioengineering Practicum II 0:1
BE 207 Mathematical Methods for Bioengineers 3:0
BE 213 Fundamentals of Bioengineering 1 2:0
BE 219 Essentials of Research and Innovation 2:0
BE 206 Biology for Engineers 3:0
BE 210 Drug Delivery: Principles and Applications 3:0

Jan semester courses
BE 203 Bioengineering Practicum I 0:1
BE 204 Bioengineering Practicum II 0:1
BE 214 Fundamentals of Bioengineering 2 2:0
BE 215 Chemistry for Bioengineers 3:0
BE 229 Statistics for Bioengineers 1:0
BE 230 Data Science for Bioengineers 2:0
BE 299 MTech Dissertation Project 0:32
BE 211 Cell Mechanics 3:0
BE 216 Dynamical Systems Biology 3:0
BE 218 Computational Epidemiology 3:1
BE 222 Stem Cell Technology 3:0
BE 223 Space Biology and Bioengineering 2:0
BE 224 Diagnostics and Devices 3:0
BE 227 Synthetic Biology and Protein Engineering 2:0
BE 228 Introduction to Mathematical Oncology 3:0

BE 203 (AUG) 0 : 1

Bioengineering Practicum 1

Siddharth Jhunjhunwala

Pre-requistes : None

References : None

BE 204 (AUG) 0 : 1

Bioengineering Practicum 2

Siddharth Jhunjhunwala

Pre-requistes : None

References : None

BE 206 (AUG) 3 : 0

Biology for Engineers

The course provides an introduction to fundamental concepts in Biology for PhD students with little to no knowledge of Biology past 10th or 12th standard school curriculum. The course will cover the following topics: biomolecules,fundamentals of biochemistry,protein structure and function, basic molecular biology,genetics,and an introduction to the cellular architecture. A combination of theoretical concepts and basic experimental methodologies in biology will be discussed. In addition, an introduction to how cells form tissues will be covered, which includes lectures on classification of tissues.The concepts covered here will aid in the skill development required to study diverse problems in bioengineering.

Ramray Bhat , Ajay Sanjay Tijore

Pre-requistes : None

References : Biology: Concepts and Connections, Third Edition. Campbell,Mitchell and Reece.~Molecular Biology of the Cell, Fourth Edition. B.Alberts, A. Johnson, J.Lewis, M.Raff, K.Roberts and P. Walter

BE 207 (AUG) 3 : 0

Mathematical Methods for Bioengineers

Bhaskara Rao Chintada

Pre-requistes : None

References : None

BE 210 (AUG) 3 : 0

Drug Delivery: Principles and Applications

The course provides an introduction to fundamental concepts in Biology for PhD students with little to no knowledge of Biology past 10th or 12th standard school curriculum. The course will cover the following topics: biomolecules,fundamentals of biochemistry, protein structure and function, basic molecular biology, genetics, and an introduction to the cellular architecture. A combination of theoretical concepts and basic experimental methodologies in biology will be discussed. In addition, an introduction to how cells form tissues will be covered, which includes lectures on classification of tissues.The concepts covered here will aid in the skill development required to study diverse problems in bioengineering. This course introduces concepts of drug delivery to meet medical challenges.The course is designed to be modular, with each module focusing on the following topics: Diffusion and permeation of drugs in biological systems;Pharmacokinetics and pharmacodynamics; Challenges and stra

Rachit Agarwal

Pre-requistes : None

References : Biology: Concepts and Connections, Third Edition. Campbell, Mitchell and Reece.~Molecular Biology of the Cell, Fourth Edition. B.Alberts,A. Johnson, J.Lewis, M.Raff, K.Roberts and P. Walter Drug Delivery: Engineering Principles for Drug Therapy,W.Mark Saltzman,Oxford University Press, 2001~Drug Delivery:Fundamentals and Applications,Anya M.Hillery and Kinam Park

BE 214 (AUG) 2 : 0

Fundamentals of Bioengineering 2

This course covers essentials of biomaterials and cell and tissue mechanics. It caters to those who want to get first exposure to the topics, which lays the foundation for advanced courses in these two topics.

Part I of the course will cover biomaterials: polymers (synthesis and properties), metals, ceramics, biocompatibility, biodegradability, key properties of biomaterials (mechanical, chemical and physical properties), protein adsorption, host response to biomaterials (innate immune response, blood coagulation and complement response), fibrosis, implant associated infections, drug delivery, tissue engineering

Part II of the course will cover cell and tissue mechanics: Cell and tissue types, Viscoelasticity of cells and tissues, mechanics of cells: cytoskeleton: contractility and movement, molecular motors for transportation within the cells, Signal transduction within the cells to achieve basic mechanics, cellular forces, stiffness sensing of cells, wound healing, mechanics of multi-joint posture and movement control

Rachit Agarwal , Medhavi Vishwakarma

Pre-requistes : None

References : Biomaterials Science, B.D. Ratner et. al., 3rd Edition, Academic Press ,2012. A Textbook of Biomechanics, S. Pal, Viva Books, New Delhi, India, 2009 An Introduction to Biomechanics, J. D. Humphrey and S. L. O'Rourke,Springer,2015 Viscoelastic Solids, R. S. Lakes, CRC Press, Boca Raton, FL, USA,1998 Muscles, Reflexes, and Locomotion, Princeton University Press, Princeton, NJ, USA,

BE 215 (AUG) 3 : 0

Chemistry for Bioengineers

This course aims to provide a fundamental understanding of chemistry to bioengineers so they can harness these concepts to solve bioengineering research challenges. The main topics that will be covered in this course are the following: 1. Bonding models including valence bond theory, molecular orbital theory, chemical forces- types and applications on biological /bi ochemical reactions.(8 lectures) 2. Quantum chemistry and application to group theory, molecular orbital theory -applications to metals in biology and bioinorganic compounds (hemoglobin) and in molecular spectroscopy.(5lectures). 3. Physical chemistry involving concepts of equilibrium reactions, electrochemistry and chemical kinetics, acid-base chemistry and its subsequent application in biomaterials and disease diagnostics. (6 lectures) 4. Coordination Chemistry-Understanding transition metal chemistry, introductions to crystal field theory to understand reactivity of biologically relevant molecules such as cisplatin, c

Sanhita Sinharay

Pre-requistes :

References : References 1. Organic chemistry- Clayden, Greeves and Warren 2. A guidebook to mechanisms in organic chemistry- Peter Sykes 3. Inorganic chemistry-principles of structure and reactivity- James Huheey. 4. Molecular Quantum Mechanics- Peter Atkins 5. Physical Chemistry- Peter Atkin

BE 302 (AUG) 3 : 0

Immunoengineering

This course introduces students to the rapidly evolving field of immunoengineering, where principles of materials science and bioengineering are applied to modulate the immune system. The course is structured into five modules: (1) Introduction to the immune system (a refresher); (2) Engineering vaccines, focusing on design strategies and delivery platforms; (3) Cellular engineering, including CAR T cells and other adoptive therapies; (4) In situ / in vivo engineering of immune responses; and (5) Antibody engineering. A unifying theme across the latter four modules is the critical role of biomaterials and drug delivery systems in engineering immune responses, making foundational knowledge in biomaterials essential. Students will explore translational applications, from implantable devices to advanced biologics, through lectures, case studies, and discussions. A significant portion of the course grade will be based on a collaborative group project, where teams will design and present an innovative immunoengineering solution to problems presented in class.

Siddharth Jhunjhunwala

Pre-requistes :
1. Undergraduate level immunology course OR equivalent; AND
2. BE 210

References : There is no prescribed textbook for this course. Listed below are a few reference books that would be useful.
1. Immunomodulatory Biomaterials and Nano-immunotherapies. Editors: Thomas J. Webster, Steven Zanganeh. 1st Edition. (Elsevier)
2. Principles of Cellular Engineering: Understanding the Biomolecular Interface. by Michael R. King. Academic Press

Nanoscience and Engineering

Preface

NE 202 (AUG) 0 : 2

Micro AND Nano Fabrication

This course is designed train student in device microfabrication at the cleanroom facility in CeNSE. The courses starts with eyes-on demonstration of the proces flow of a p-n junction solar cell or MOSFET. Next, the students will execute a microfabrication heavy project which exposes them to design-of-experiment, process development, and troubleshooting

Shankar Kumar Selvaraja , Sushobhan Avasthi

Pre-requistes **:**

References : None

NE 215 (AUG) 3 : 0

Applied Solid State Physics

This course is intended to build a basic understanding of solid state science, on which much of modern device technology is built, and therefore includes elementary quantum mechanics and EM theory. Principle of thermal equilibrium, concept of entropy, Boltzmann factor, Blackbody radiation, H-atom, Wave nature, uncertainty principle, wave equation, application to particle in a box, scattering, different quantum numbers, Dirac notation and application to SHO Idea of operator and commutation Unitary operator, Hilbert space, Time independent perturbation theory, Fermi Golden rule, spin and statistics MB, FD and BE statistics, crystal structure, reciprocal lattice, lattice vibrations, free electrons, electrons in periodic potential, bands, quantization: photon, phonon, excitations, Maxwells equations in vacuum, insulating and conducting media, Fresnel equations Interference, diffraction and polarization quantum description Interaction of light with two level system

Chandan Kumar

Pre-requistes : None

References : Books for CMP/SSP part: Kittel, Ashcroft & Mermin Books for Quantum Mechanics: Grffiths Books for EMT: Griffiths

NE 222 (AUG) 3 : 0

MEMS: Modeling, Design, and Implementation

This course discusses all aspects of MEMS technology –from modeling, design, fabrication, process integration, and final implementation. Major emphasis will be placed on developing a wholistic view of MEMS and NEMS systems by not only giving consideration to physics of the device but also taking into account fabrication technologies required for manufacturing the device, readout circuits and other electronics and packaging. The course covers device fabrication techniques such as bulk and surface micromachining. Different levels of modelling such as back-of-the envelop calculations to solution of coupled partial differential equations solutions using FEM techniques will be discussed. A wide range of fundamental physicsneeded to design MEMS devices including, but not limited to, thermal circuits, linear and non-linear spring-mass damper systems, electrostatics, piezoresistivity, piezoelectricity etc. These concepts will be discussed in context of various practical MEMS and NEMS devices such as accelerometers, gyroscopes, micro-bolometers, timing-references, mass spectrometers etc. Finally, integration of micromachined mechanical devices with microelectronics circuits for complete implementation is also discussed.

Saurabh Arun Chandorkar

Pre-requistes : None

References : 1.Stephen D. Senturia, “Microsystem Design”, Kluwer Academic Publishers, 2ndPublishing, 2001. 2.G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat and V.K. Aatre, “Micro and Smart Systems”, Wiley India, 2010.

NE 231 (AUG) 3 : 0

Microfluidics

This is a foundation course discussing various phenomena related to fluids an fluid-interfaces at micro-nano scale. This is a pre-requisite for advanced courses and research work related to micro-nano fluidics. Transport in fluids,equations of change, flow at micro-scale, hydraulic circuit analysis, passive scalar transport, potential fluid flow, stokes flow Electrostatics and electrodynamics, electroosmosis, electrical double layer (EDL), zeta potential,species and charge transport, particle electrophoresis,AC electrokinetics Surface tension, hysteresis and elasticity of triple line, wetting and long range forces, hydrodynamics of interfaces, surfactants, special interfaces Suspensions, rheology,nanofluidics, thick-EDL systems, DNA transport and analysis

Prosenjit Sen

Pre-requistes : None

References : Brian J. Kirby, Micro- and Nanoscale Fluid Mechanics, Cambridge University Press,P.-G. de Gennes, F. Brochard-Wyart, and D. Quere, Capillarity and Wetting Phenomena, Springer,R. F. Probstein, Physicochemical Hydrodynamics,Wiley Inter-Science,-,-

NE 313 (AUG) 3 : 0

Lasers: Principles and Systems

This is an intermediate level optics course which builds on the background provided in “Introduction to photonics” offered in our de partment. Owing to the extensive use of lasers in various fields, we believe a good understanding of these principles is essential for students in all science and engineering disciplines.

Supradeepa V R , Balaswamy Velpula

Pre-requistes : None

References : Anthony E. Siegman, Lasers, University Science Books (1986), OrazioSvelto, Principles of Lasers, Springer (2010),Miscellaneous Resea rch Articles and Reviews.

NE 314 (AUG) 3 : 0

Semiconductor Opto-electronics and Photovoltaics

An advanced graduate level course, NE314 provides a detailed overview of various optoelectronic devices such as LEDs, photodetectors and solar cells. The focus is more on the device physics, though some material and fabrication issues are also discussed. The course is designed for students who have a background in semiconductor device physics. A basic device course, such as NE205, is a strongly suggested prerequisite.

Aditya Sadhanala

Pre-requistes : None

References : None

NE 240 (AUG) 3 : 0

Materials design principles for electronic, electromechanical and

Module 1:Structure and symmetry, property predictions from symmetry: piezoelectricity, electrostriction, ferroelectricity, second harmonic generation Module 2:Equilibrium property predictions from thermodynamics, order parameters elementary statistical mechanics of phase transitions, Landau theory, property enhancements near second order phase transitions Module 3:Dissipative properties, entropy generation, Onsager’s formulation, hysteresis, electrical and thermal transport, electrical /thermal resistance, thermoelectric properties Module 4:Defects, kroger-vink notation, defects as property deteriorating entities, defects as property enhancing entities, Recent f indings on designing new properties through defects and their kinetics (revisit of ferroelectricity and electromechanical responses of defective compounds) Tight binding band structure, perturbation by defects, physics of amorphous solids and their electronic properties. Correlations (if time permits), and metal-insulator transitions.

Pavan Nukala

Pre-requistes : None

References : 1.Physical properties of crystals, J.F. Nye 2.Properties of materials, anisotropy, symmetry and structure, R.E.Newnham 3.Properties of non-crystalline solids, Mott and Davies 4.Research papers

NE 201B (AUG) 0 : 2

Lab for structural and functional characterization

This is a laboratory course designed to train students in various device and material characterization techniques. Following techniques will be covered under the course: XRD, electron diffraction and microscopy such as TEM, SEM, Elastic vs. inelastic Energy loss/spectroscopy/EELS, XPS/XAS. Photoluminescence, Raman Spectroscopy, Confocal and fluorescence microscopy, Optical profilometer/UV-vis/ellipsometer, basics of FTIR, Atomic Force Microscope, including CAFM, KPFM, Basics of electrical measurements including resistivity, 4-probe, Hall, TLM, van der Pauw, Capacitance-Voltage measurement including MOS C-V, theory and working of lock-in amplifier; low frequency highly sensitive measurements, Opto-electronics measurements including measuring detectivity, photo current and noise of photodetector, basics of LED measurements, Basics of high-frequency measurement – needle probe vs CPW, oscillos cope/function generator, basics of VNA and small-signal parameters

Akshay K Naik

Pre-requistes :

References : Notes

NE 201A (AUG) 3 : 0

Theory of structural and functional characterization

This course provides theoretical framework for various device and material characterization techniques. Following techniques will be covered under the course: XRD, electron diffraction and microscopy such as TEM, SEM, Elastic vs. inelastic Energy loss/spectroscopy/EELS, XPS/XAS. Photoluminescence, Raman Spectroscopy, Confocal and fluorescence microscopy, Optical profilometer/UV-vis/ellipsometer, basics of FTIR, Atomic Force Microscope, including CAFM, KPFM, Basics of electrical measurements including resistivity, 4-probe, Hall, TLM, van der Pauw, Capacitance-Voltage measurement including MOS C-V, theory and working of lock-in amplifier; low frequency highly sensitive measurements, Opto-electronics measurements including measuring detectivity, photo current and noise of photodetector, basics of LED measurements, Basics of high-frequency measurement – needle probe vs CPW, oscilloscope/function generator, basics of VNA and small-signal parameters

Akshay K Naik

Pre-requistes :

References : Lecture notes

NE 303 (AUG) 2 : 1

Semiconductor Process Integration

The course teaches the art and science of semiconductor process integration. The courses will discuss module-level integration issues that come up in complex device fabrication. In the first 4 weeks, we will discuss technologically relevant modules like LOCOS, shallow trench isolation, replacement metal gate, Damascene and dual-Damascene, etc. In the next 9-10 weeks, we will discuss case studies on six advanced devices with complex fabrication flows. The basket of courses will change with time but examples include, leading-node logic, memory, integrated photonics, solar cells, microelectromechanical systems, light emitting device, and heterogenous integration. The course has 1 lecture per week of instructor-led teaching. The lecture will discuss case studies. In parallel, we will have weekly take-home lab-assignment on TCAD software like SEMulator3D. We will organise 1 take-home lab per week. The lab will be in the form of an assignment, where students will be required to submit a report, which will be graded. The lab session,will be supported by 1 tutorial session per week. The tutorial will be organised to help answer questions. It will be primary run by TA(s).

Sushobhan Avasthi

Pre-requistes :

References : 1. Introduction to Microfabrication by Sami Franssila, Wiley 2.Silicon Devices and Process Integration - Deep Submicron and Nano-Scale Technologies by Badih El-Kareh, Springer 3. Materials & Process Integration for MEMS, Francis E. H. Tay, Springer 4. Handbook of 3D Integration by Christopher Bower, Peter Ramm, Philip Garrou, Wiley Solar Photovoltaics Technology, System Design,

NE 203A (AUG) 3 : 1

Advanced micro and nanofabrication technology and process

Introduction and overview of micro and nano fabrication technology.Safety and contamination issues in a cleanroom. Overview of cleanroom hazards. Basic process flow structuring. Wafer type selection and cleaning methods. Additive fabrication processes. Material deposition methods. Overview of physical vapour deposition methods (thermal, e-beam, molecular beam evaporation) and chemical vapour deposition methods(PE-CVD, MOCVD, CBE, ALD). Pulsed laser deposition (PLD), pulsed electron deposition (PED). Doping: diffusion and ion implant techniques.Optical lithography fundamentals, contact lithography,stepper/ canner lithography, holographic lithography, direct-laser writing.Lithography enhancement methods and lithography modelling. Non-optical lithography;E-beam lithography, ion beam patterning, bottom-up patterning techniques. Etching process: dry and wet. Wet etch fundamentals,isotropic,directional and anisotropic processes. Dry etching process fundamentals,plasma assisted etch process, Deep Reactive Ion Etching (DRIE), Through Silicon Vias (TSV). Isotropic release etch. Chemical-mechanical polishing (CMP),lapping and polishing. Packaging and assembly, protective encapsulating materials and their deposition. Waferdicing, scribing and cleaving. Mechanical scribing and laser scribing,Wafer bonding, die-bonding. Wire bonding, die-bonding.Chip-mounting techniques. Simulation-based assignments on the above topics

Shankar Kumar Selvaraja , Sushobhan Avasthi

Pre-requistes : None

References : Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication~Sorab K. Gandhi, VLSI Fabrication Principles: Silicon and Gallium Arsenide~Richard C. Jaeger, Introduction To Microelectronic Fabrication

NE 206A (AUG) 3 : 1

Semiconductor Device Physics: Basic Devices

An graduate level course, NE206 provides an introduction to semiconductor device physics. The focus is on basics like the origin of band-structure, carrier transport, thermal statistics, junctions, defects, and interfaces. Schottky diodes, p-n junction diodes, bipolar junction transistors, and MOS transistors are covered in detail. This is a fundamental course for anyone interested in electronic devices. TThe lab component will use simulation-based assignments to complement the theory part of the course.Topics include, energy bands in solids; Fermi-Dirac distribution; doping; density of states; low-field transport; high-field transport; carrier flow by diffusion and drift; Excess carriers and recombination processes; PN junction at thermal equilibrium & bias; Transient behavior of p-n junction; metal- semiconductor (Schottky and Ohmic junctions; Current transport mechanisms; BJT; MOS capacitor; MOSFET; Short channel effects;advanced CMOS devices Laboratory component based on simulation assignments. Topics similar to above.

Sushobhan Avasthi

Pre-requistes : None

References : “Introduction to Semiconductor Materials & Devices”, by M.S.Tyagi "Physics of semiconductor devices", by S M Sze, Wiley Indi “Semiconductor Device Physics and Design”, by Umesh Mishra and Jasprit Singh, Springer “Physical Foundations of Solid State Devices”, by E. F. Schubert (e-book available free at http://nadirpoint.de/Physik_Lit_PDF/65.pdf)

Computational and Data Sciences

Preface

DS 200 (AUG) 0 : 1

Research Methods

This course will develop the soft skills required for the CDS students.The modules (each spanning 3 hours) that each student needs to complete include:Seminar attendance, literature review, technical writing (reading, writing,reviewing), technical presentation, CV/resume preparation, grant writing,Intellectual property generation (patenting), incubation/start-up opportunities, and academia/industry job search.

Debnath Pal

Pre-requistes : None

References : None

DS 201 (AUG) 2 : 0

Bioinformatics

Unix utilities, overview of various biological databases (Protein Data Bank,structural classification of proteins, genome database and Cambridge structural database for small molecules), introduction to protein structures,introduction to how to solve macromolecular structure using various biophysical methods, protein structure analysis,visualization of biological macro molecules, data mining techniques using protein sequences and structures. short sequence alignments,multiple sequence alignments, genome alignments,phylogenetic analysis, genome context-based methods, RNA and transcriptome analysis, mass spectrometry applications in proteome and metabolome analysis, molecular modeling, protein docking and dynamics simulation. Algorithms, scaling challenges and order of computing in big biological data.

Debnath Pal

Pre-requistes : None

References : C.Branden and J.Tooze (eds) Introduction to Protein Structure, Garland,1991~Mount, D.W., Bioinformatics: Sequence and Genome Analysis, Cold. Spring Harbor Laboratory Press,2001.~Baxevanis, A.D., and Ouellette, B.F.F. (Eds), Bioinformatics: A practical guide to the analysis of the genes and proteins,Wiley-Interscience, 1998

DS 221 (AUG) 3 : 1

Introduction to Scalable Systems

1) Architecture: computer organization, single-core optimizations including exploiting cache hierarchy and vectorization, parallel architectures including multi-core, shared memory, distributed memory and GPU architectures; 2)Algorithms and Data Structures: algorithmic analysis, overview of trees and graphs, algorithmic strategies, concurrent data structures; 3) Parallelization Principles: motivation, challenges, metrics, parallelization steps, data distribution, PRAM model; Parallel Programming Models and Languages: OpenMP,MPI, CUDA; 4) Big Data Platforms: Spark/MapReduce model, cloud computing. Lab tutorials and programming assignments for above topics.

Sathish S Vadhiyar , Chirag Jain

Pre-requistes : None

References : None

DS 252 (AUG) 3 : 1

Cloud Computing

Distributed Systems Foundations.
Cloud Service and Deployment Models.
Virtualization and Container Runtimes.
Cloud Storage Services and Scaling Costs.
Serverless Orchestration.
Cloud Security & Policies.
DevOps & Observability.
Cloud-Native MLOps Pipelines.
Edge Computing & Edge–Cloud Continuum.
Emerging topics on Agentic Cloud Workflows, Quantum Computing in the Cloud.

Yogesh L Simmhan

Pre-requistes :
CS major in undergraduate, Introduction to Scalable Systems, or any other prior systems course.
References : LLM Agents guided by course curriculum framework. Notes and papers.

DS 284 (AUG) 2 : 1

Numerical Linear Algebra

Introduction: Matrix and vector norms, arithmetic and computational complexity, floating point arithmetic. Matrix factorization and direct methods for solving linear systems: Gaussian elimination, LU factorization, Pivoting,Cholesky decomposition, QR factorization, Gram-Schmidt orthogonalization,Projections, Householder reflectors, Givens rotation, Singular Value Decomposition, Rank and matrix approximations, image compression using SVD,generalized Schur decomposition (QZ decomposition), Least squares and solution of linear systems and pseudoinverse, normal equations. Stability Analysis:conditioning of a problem, forward and backward stability of algorithms,perturbation analysis. Eigenvalue problems: Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations, Power method, Schur decomposition, Jordan canonical form, QR iteration with & without shifts,Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem,Jacobi method, Divide and Conquer, Iter

Phani Sudheer Motamarri

Pre-requistes : None

References : None

DS 288 (AUG) 3 : 0

Numerical Methods

Root finding: Functions and polynomials, zeros of a function, roots of a nonlinear equation, bracketing, bisection, secant, and Newton Raphson methods. Interpolation, splines, polynomial fits, Chebyshev approximation. Numerical Integration and Differentiation: Evaluation of integrals, elementary analytical methods, trapezoidal and Simpson’s rules, Romberg integration,Gaussian quadrature and orthogonal polynomials, multidimensional integrals,summation of series, Euler-Maclaurin summation formula, numerical differentiation and estimation of errors. Optimization: Extremization of functions, simple search, Nelder-Mead simplex method, Powell’s method,gradient-based methods, simulated annealing. Complex analysis: Complex numbers, functions of a complex variable, analytic functions, conformal mapping ,Cauchy’s theorem. Calculus of residues. Fourier and Laplace Transforms,Discrete Fourier Transform, z transform, Fast Fourier Transform (FFT),multidimensional FFT, basics of numerical optimizat

Ratikanta Behera

Pre-requistes : None

References : None

DS 215 (AUG) 3 : 0

Introduction to Data Science

Course Description: This three credit course will be offered every August - December term as a hardcore course in the Dept. of Compu tational and Data Sciences (CDS). This is designed to be an introductory graduate level course (200-series) with an aim to equip first year graduate students (M.Tech./Ph.D.) with the necessary fundamentals as well as various statistical tools and techniques to analyze, estimate, learn and infer from data. At the end of the course, the students should be able to parse a real-world data analysis problem into one or more computational components learned in this course, apply suitable statistical inference/machine learning techniques and analyze the results obtained to enable optimal decision making. This would also act as a first course in data science and provide necessary prerequisites and knowledge to explore more specialized and involved topics in machine learning, analytics, statistics etc. Detailed Syllabus:- Probability and Statistics Primer: Fun

Anirban Chakraborty

Pre-requistes :

Undergraduate level knowledge of linear algebra, multivariate

References : 1. Athanasios Papoulis and S. Unnikrishna Pillai, Probability, Random Variables and Stochastic Processes, McGraw Hill Education, 2017. 2. Alberto Leon-Garcia, Probability, Statistics, and Random Processes for Electrical Engineering, 3rd Edition, Pearson, 2008. 3. Steven M. Kay, Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory, Pearson, 1993. 4. Jerome H.

DS 307 (AUG) 3 : 0

Ethics In AI

We interact with AI technology on a daily basis—such systems answer the questions we ask, solve complex tasks, curate the content we read, unlock our phones, allow entry to airports, etc. Further, with the recent advances in large language and vision models, the impact of such technology on our lives is only expected to grow. This course introduces students to ethical implications associated with design, development and deployment of AI technology spanning NLP, Vision and Speech applications.

Danish Pruthi

Pre-requistes : The class is intended for graduate students and senior undergraduates. Students would most benefit if they have finished at least a basic machine learning course from IISc (or similar-quality course elsewhere) and any one courses related to the discussed applications (computer vision, speech or NLP). There are no hard pre-requisites, we trust students to self assess whether this course is for

References : Recent papers spanning: ethical theories, data collection and curation, biases and algorithmic fairness, debiasing and mitigating harms, AI for Global South, content moderation: misinformation, disinformation and hate-speech, understanding AI systems: transparency, accountability, (lack of) interpretability, alignment and safety of AI systems, implications of AI-generated content,

DS 299A (AUG) 0 : 12

Dissertation Project A

Split of the Dissertation Project to be evaluated in the August term

Phani Sudheer Motamarri

Pre-requistes : None

References : Not Applicable

Management Studies

Preface

MG 261 (AUG) 3 : 0

Operations Management

Introduction to Production/Operations Management (P/OM), P/OM strategy, forecasting, process management, facility layout, capacity planning and facility planning, aggregate planning, material requirement planning, scheduling, inventory management, waiting line, project management, management of quality. Introduction to simulation and to supply chain management.

Shashi Jain

Pre-requistes : None

References : Stevenson,William,J.,Production/Operations Management. 6th Edition. Irwin/McGraw-Hill.,Krishnaswamy

MG 201 (AUG) 3 : 0

Managerial Economics

Introduction to managerial economics, demand theory and analysis, productiontheory, cost theory, market structure and product pricing, Pricing of goods and services, pricing and employment of inputs. Micro and macro economics,national income accounting, GDP measurement, inflation and price level,aggregate demand and supply, fiscal and monetary policy.

Sumirtha Gandhi

Pre-requistes : None

References : Allen,Bruce et al: Managerial Economics: Theory,Applications,and Cases,WW Norton

MG 212 (AUG) 2 : 1

Behavioral Science

Understanding human behaviour; functionalist, cognitive, behaviouristic and social learning theories; perception; learning; personality; emotions; defense mechanisms; attitude; communication; decision making; groups and social behaviour; intra-personal and inter-personal differences; managing conflicts.

Anjula Gurtoo

Pre-requistes : None

References : Luthans,F,Organizational Behaviour,McGraw-Hill,1988. Weiten

MG 225 (AUG) 3 : 0

Decision Models

Analytical hierarchy process: structuring of a problem into a hierarchy consisting of a goal and subordinate features of the problem, and pairwise comparisons between elements at each level. Goal programming: Pareto optimality, soft constraints, identifying the efficient frontier, duality and sensitivity analysis. Data envelopment analysis: relative efficiency measurements, DEA model and analysis, graphical representation, and dual DEA model. Agent based modeling: complex adaptive systems, emergent structures and dynamic behaviors. Discrete event simulation: random number generators and generating random variates. Selecting input probability distributions and output data analysis. Neural networks: neuron model and network architecture, perceptron learning rule, and back propagation. Support vector machines: Learning methodology, linear learning machines, kernel-induced feature spaces.

Parthasarathy Ramachandran

Pre-requistes : None

References : None

MG 241 (AUG) 3 : 0

Marketing Management

Marketing function, marketing concept, relationship with other functions,relevance, marketing environment, markets. Consumer behavior, market segmentation, marketing planning, marketing mix, Product policy, new products,product life cycle. Pricing, distribution. Advertising and promotion.Marketing organization. Sales forecasting. Management of sales force,marketing control.

Shashi Jain

Pre-requistes : None

References : None

MG 251 (AUG) 3 : 0

Finance and Accounts

Nature and purpose of accounting, financial statements: learning, understanding the basic financial statements. Preparation of P and L account,balance sheet, basic accounts and trial balance. Income measurement, revenue recognition, depreciation accounting. Cash flow statements. Analysis and interpretation of financial statements; concepts and elements of cost,activity based costing. CVP analysis, break-even point, marginal costing,relevant costing. Cost analysis for decision making: opportunity cost concept, dropping a product, pricing a product, make-or-buy and product mix decisions.Joint products, by- products. Process costing. Standard costing, budgeting – flexible budget, master budget, zero based budgeting. Overview of Financial Management, time value of money, fund and cash flow statement, risk and return. Working capital management: estimating working capital, financing working capital, receivables management, inventory management, cash management, money markets in India. Capital Budgeting: appraising long term investment projects, make vs. buy investment decisions, estimating relevant cash flow. Capital Structure: Estimation of cost of debt, cost of equity, overall cost of capital, CAPM. Capital structure planning: Capital structure policy and target debt equity structure, EBIT-EPS analysis. Leasing. Introduction to valuation of firm. Introduction to derivatives.

Shashi Jain

Pre-requistes : None

References : None

MG 265 (AUG) 3 : 0

Data Mining

Introduction to data mining. Data mining process. Association rule mining:Apriori and FP tree. Classification: ID3, C4.5, Bayes classifier. Clustering:K-means, Gaussian mixture model. Bayesian belief networks. Principal component analysis. Outlier detection.

Parthasarathy Ramachandran

Pre-requistes : None

References : Jiawei Han and Micheline Kamber, Data Mining: Concepts and Techniques, Morgan Kaufman Publishers 2001.,Richard J. Roiger and Michael W Geatz, Data Mining: A Tutorial-Based Primer, Addison-Wesley 2003,Mehmed Kantardzic, Data Mining:Concepts, Models, Methods and Algorithms, Wiley, 2003

MG 229 (AUG) 3 : 0

Regression and Time Series Analysis

Review of Regression and Best Linear Prediction. Simple and Multiple Linear Regression - Uniformly Minimum Variance Unbiased Estimation, General Linear Hypotheses Testing, Prediction. Correlation Analysis - Simple, Multiple and Partial Correlations. Model Building - Feature Selection, Interactions, Transformations, Dummy Variable Techniques, Residual Analysis. Classical Decomposition of Time Series into Trend, Cyclical, Seasonal and Irregular Components. Stationary Stochastic Processes. Autocorrelation, Partial Autocorrelation, Impulse Response and Forecast Functions of Moving Average, Auto Regressive and ARMA Processes. Fitting ARMA Models. Trend Modeling - Deterministic versus Stochastic Trends, Integrated Processes, Unit Root Tests. Fitting, Interpreting and Forecasting using ARIMA Models. Seasonality Modeling – SARIMA Models.

Mukhopadhyay C

Pre-requistes : MG220 or equivalent

References : • Applied Linear Statistical Models by Michael H. Kutner,Christopher J. Nachtsheim, John Nete and William Li,,McGraw-Hill, International Edition.
• Introduction to Time Series and Forecasting by Peter J. Brockwell Richard A. Davis. Second Edition, Springer.

MG 219 (AUG) 3 : 0

Introductory Probability Theory

Interpretation of Probability. Definition of Probability Space. Combinatiorial Probability. Probability Laws - Complementation, Addition and Multiplication Law. Conditional Probability. Bayes Theorem. Random Variables – Probability Mass Function, Probability Density Function, Cumulative Distribution Function, Moments & Quantiles. Chebyshev’s Inequality. Jointly Distributed Random Variables – Joint, Marginal & Conditional Distributions, Covariance, Correlation & Regression. Properties of Expectation, Variance, Covariance, Correlation and Regression. Probability Generating Function, Moment Generating Function and Characteristic Function. Discrete Probability Models – Bernoulli, Binomial, Hypergeometric, Geometric, Negative Binomial and Poisson Distributions. Poisson Process. Continuous Probability Models – Uniform, Exponential, Gamma, Beta, Weibull and Normal Distributions. Almost Sure, in Probability, in Moment and in Distribution Convergence of Random Variables. Law of Large Numbers. Central Limit Theorem.

Mukhopadhyay C

Pre-requistes : Multivariable Calculus and Linear Algebra

References : • A First Course in Probability by Sheldon Ross. Eighth Edition, 2010. Prentice Hall.
• Introduction to Probability Theory by Paul G. Hoel, Sidney C. Port and Charles J. Stone. 1971. Houghton Mifflin.
• Elementary Probability Theory with Stochastic Processes by Kai Lai Chung. Third Edition, 1974. Narosa Publishing House.

Energy Research

Preface

The academic programs (MTech (Res) and PhD) in the Energy Research centre are aimed towards advancing knowledge and skills related to the design of efficient energy conversion and storage processes and devices, utilization of energy resources- conventional fossil fuels to renewable sources such as solar, and waste-energy harvesting, and materials discovery and engineering. The program is open to students with diverse backgrounds in engineering and sciences and focus on equipping and training students to contribute to India's energy transition.

ER 201 (AUG) 3 : 0

Renewable Energy Technologies

Energy is a critical component in the daily life of mankind. Historically, energy production technologies have shown a continual diversification depending on technological, social, economical, and even political impacts. In recent times, environmental and ecological issues have also significantly affected the energy usage patterns. Hence, renewable energy sources are occupying increasingly important part of the emerging energy mix. This course gives an introduction to key renewable energy technologies. Case studies will be discussed to emphasize the applications of renewable energy technologies. At the end of the course students should be able to identify where, how and why renewable energy technologies can be applied in practice.

Pradip Dutta

Pre-requistes : None

References : None

ER 208 (AUG) 3 : 0

Introduction to Micro Energy Harvesting

Introduction to micro energy harvesting. Micro energy harvesting using piezoelectric, triboelectric, electrostrictive, flexoelectric, and electrostatic electromechanical couplings. Micro-electromechanical systems (MEMS), nanogenerators, and sensors. Hydrovoltaic energy harvesting from water interaction with materials using water waving, evaporation, moisture, drawing, reverse electrodialysis, and reverse electrowetting processes. Pyroelectric, thermoelectric, magnetoelectric effects-based micro energy harvesting. Radio Frequency (RF) and non-RF micro energy harvesting. Materials in micro energy harvesting, roles of material design in the enhanced energy harvesting performance, basics of micro energy harvesting device fabrication, and applications of micro energy harvesting. Recent developments, renewability, and sustainability in micro energy harvesting.

Farsa Ram

Pre-requistes : None

References : Book:
1. Micro Energy Harvesting by Danick Briand, Eric Yeatman, Shad Roundy, Link: https://www.wiley.com/en-us/Micro+Energy+Harvesting-p-9783527672929

ER 210 (AUG) 3 : 0

Heat and Mass Transfer

Techniques to solve the heat equation: Simplification, Superposition, Separation of variables, Similarity solutions. Modelling approaches for real systems. Multi-dimensional unsteady conduction: product solutions. Boundary layer momentum, energy equations - Falkner-Skan transformation, Graetz problem. Natural convection heat transfer. Turbulent heat transfer. Radiation - Spectral, directional effects, interacting media. Mass transfer - Analogy to heat transfer, low mass transfer rate assumption. Simultaneous heat and mass transfer: evaporation, wet-bulb temperature.

Jaichander Swaminathan

Pre-requistes : None

References : 1. Heat Transfer, A. F. Mills
2. A Heat Transfer Textbook, Lienhard and Lienhard, https://ahtt.mit.edu/

ER 202 (AUG) 3 : 0

Thermodynamics of Energy Systems

Laws of thermodynamics, Application to processes (batch and steady-state) involving pure species, Concepts of availability and exergy, Property packages and computational tools for thermodynamic analysis, Equation of state, Maxwell's relations, Chemical equilibria and ionization, Gibbs and Helmholtz functions, Psychrometrics, Power and refrigeration cycles, Rational efficiencies of heat engines, Waste heat recovery, Fuel cells, Nozzles and blade passages, Introduction to gas turbines.

Pramod Kumar

Pre-requistes : None

References : Fundamentals of Thermodynamics. Borgnakke, Sonntag. Wiley
Fundamentals of Engineering Thermodynamics. Moran, Shapiro, Boettner, Bailey. Wiley
Advanced Engineering Thermodynamics. A Bejan. Wiley

Water Research

Preface

WR 201 (AUG) 2 : 1

Watershed Modeling

Course description: This course will cover the concepts of watershed modeling. This three-credit course will be offered as an elective every year in the August-December term in the ICWaR. This course is aimed to be an introductory graduate-level (200-series) course, typically with Water Resources Engineering background. In-class lectures include basic and advanced topics related to surface hydrology. Additionally, the basics of computer methods in hydrology will be discussed. Tutorial sessions on MATLAB, MS Excel, and ArcSWAT will be conducted. Calibration and validation of ArcSWAT (distributed model) and HYMOD (lumped model) will be performed during tutorial sessions. Topics 1. Introduction to watershed modeling Runoff generation and streamflow. Spatio-temporal scales in watershed modeling. Watershed properties. 2. Pre-processing of model inputs Understanding watershed model inputs. Basics of MATLAB computations. Hydrologic data processing in MATLAB. 3. Data-driven watershed models Stochastic models (ex: Quantile regression). Neural network models. 4. Different watershed models Lumped/ Distributed/ Physical/ Conceptual watershed models. Thornwaite-type water balance model. Thomas model (abcd) model. Data assimilation in abcd model. Introduction to ArcSWAT and HYMOD. Flood forecasting. Performance measures. 5. Predicting the future Future hydrologic projections. Impact of climate change on river discharge. Uncertainty in river discharge estimation. Tutorial Sessions Processing of Geospatial and temporal data for watershed modeling. MATLAB tutorials. 'abcd' model set-up in MS Excel. Stochastic and NN model setup in Matlab. Calibration and validation of HYMOD and ArcSWAT. Development of forecast models.

Rajarshi Das Bhowmik

Pre-requisites :

References : Textbooks: Dingman, S. L. (2015). Physical hydrology. Waveland press. Singh, V. P., & Frevert, D. K. (Eds.). (2010). Watershed models. CRC press.

WR 203 (AUG) 2 : 1

Applied geochemical modeling and Water quality analysis

Simulation and modelling • Introduction to the Storm Water Management Model (SWMM) in Urban Catchments (4 hr) • Tutorial on BRAT (Basic Radar Altimetry Toolbox) (4 hr) • Tutorial on Remote Sensing (4 hr) • Introduction to Climate/Earth System Modeling (4 hr) Basic electronic instrumentation (6 hr) Measurements of ionic contaminants using an ICPMS and IC (6 hr) Water Quality (1 hr) • To assess the alkalinity of a given water sample. (1 hr) • Determine chloride ion concentration in a water sample. (1 hr) • To assess the total solids of a given sample of water. (1 hr) • Measure Total hardness using dye indicators. (1 hr) • To introduce concepts of total coliforms using the multiple-tube fermentation technique. (2 hr) • To assess the color of the given water sample. (1 hr) • Determine the DO content of a given sample. (1 hr) • To assess the pH value of the given water samples. (1 hr) • To assess the residual chlorine of the given water sample. (1 hr)

Praveen Ramamurthy

Pre-requisites :

None

References : ITM User's Manual available at the web site http://web.engr.oregonstate.edu/~leon/ITM.htm

Chavez, P.S., 1996. Image-based atmospheric corrections-revisited and improved. Photogramm. Eng. Remote Sens. 62, 1025-1036.

Cyber Physical Systems

Preface

The Center for Cyber-Physical Systems focuses on interdisciplinary areas including robotics, control and optimization, mobility and urban intelligence, and energy management. The courses are designed to provide good theoretical background and hands-on experience in these areas. The center offers three programs - PhD, MTech (Research) and MTech in Robotics and Autonomous Systems.

CP 212 (AUG) 2 : 1

Design of Cyber-Physical Systems

This course will be taught jointly with Dr. Ashish Joglekar and Darshak Vasavada. This is an interdisciplinary course on the design of cyber- physical systems, inviting students from all the departments. It provides an in-depth exposure to various elements of a CPS: the microprocessor, interfacing physical devices (analog and digital) and control systems basics. This course uses a practical approach and involves significant programming. Syllabus: 1. Microprocessor system 2.Interfacing physical devices 3.Control systembasics 4.EMI/ EMC considerations 5.Network connectivity

Pandarasamy Arjunan

Pre-requistes : None

References : Embedded Systems: a CPS approach: Lee and Seshia~Embedded Systems -Shape the World: Valvano and Yerraballi~Basics of Microprocessor Programming: Darshak Vasavada and S K Sinha

CP 214 (AUG) 3 : 1

Foundations of Robotics

NOTE: This course is cross-listed with CSA (soft core for CSA) Motivation and objective: As we see an increasing use of industrial and service robots around us, there is a need for development of new skills in the field of robotic systems. More importantly, there is a need for development of new expertise in controllers, systems, sensors and algorithms that are tailored for the domain of robotic systems. Therefore, the objective of this course is to serve as an introductory robotics course for EECS students with little/no background in mechanical systems. The course will first build the necessary mathematical framework in which to understand topics relevant to fundamentals of mechanical systems. Some of the topics are center of gravity and moment of inertia, friction, statics of rigid bodies, principle of virtual work, kinematics of particles and rigid bodies, impacts, Newtonian and Lagrangian mechanics. With these fundamentals, the course will focus on topics like rigid body trans

Shishir Nadubettu Yadukumar

Pre-requistes : None

References : Ruina, Andy and Pratap, Rudra, Introduction to Statics and Dynamics, Oxford University Press, 2011.~Murray, Li and Sastry, A Mathematical Introduction to Robot Manipulation, CRC Press, 1994~A. Ghosal, Robotics: Fundamental Concepts and Analysis, Oxford, 2006

CP 320 (AUG) 3 : 0

Operations Research for Mobility Management

This course will introduce operations research (OR) techniques applied to cyber-physical systems (CPS), with an emphasis on decision making for mobility management. Urban mobility is evolving from a fixed supply chain that delivers process-driven travel to a dynamic ecosystem that delivers on-demand services. This new mobility model requires optimization across multiple systems such as transportation, parking, electric vehicle charging and vehicle-to-grid services, etc. The complexity, therefore, arises from the large scale of operations; heterogeneity of system components; dynamic and uncertain operating conditions; and goal-driven decision making and control with time-bounded task completion guarantees. The focus in this course will be on various classical optimization techniques and learning to optimize approaches that can be applied to solve operational problems at scale in the urban mobility domain. Examples of some decision questions include planning/ scheduling charging operations for a fleet of electric vehicles; dynamic pricing for charging demand management; electric vehicle route planning for last-mile delivery of goods and other valued-added services (such as selling energy back to the grid); operations management of mixed fleet of vehicles; etc. Selective operations research topics such as linear programming and combinatorial optimization; dynamic programming; sequential decision making under uncertainty; reinforcement learning; etc.; will be covered to understand the mathematical concepts for problem solving in mobility management. This course will be relevant to both computer science and electrical engineering students, as well as benefit those specializing in cyber physical systems and sustainable transportation

Punit Rathore

Pre-requistes :

A preliminary understanding of mathematical programming would

References : • Wayne L. Winston (2003). Operation Research: Applications and Algorithms • Nocedal and Wright (2006). Numerical Optimization (Springer Series in Operations Research) • Norving and Russel (2010). Artificial Intelligence: A Modern Approach (Prentice Hall Series in Artificial Intelligence) • Sutton and Barto (2018). Reinforcement Learning: An Introduction

CP 241 (AUG) 2 : 1

Applied Linear and Nonlinear Control

Linear Systems - Mathematical representation of dynamical systems, State-space and input-output representations, Time response of homogeneous and non-homogeneous systems, Stability, Controllability and observability, State feedback controllers and pole placement, State observers, LQR control, PID control

Nonlinear Systems – Mathematical background for nonlinear systems, Equilibrium points, Essential nonlinear phenomenon like finite escape time, multiple isolated equilibria, limit cycle, chaos etc. Lyapunov and input-state stability, Control Lyapunov functions, Feedback linearization, Model predictive control

Lab - Simulation of linear, nonlinear, and hybrid control systems, Phase-space visualizations, Implementation of different controllers on various robotics and autonomous systems.

Pushpak Jagtap

Pre-requistes :

References : 1. A Linear Systems Primer by Antsaklis and Michael, Birkhauser, 2007.
2. Linear Systems Theory by Hespanha, Princeton University Press (2nd Edition), 2018.
3. Linear System Theory and Design by Chen, Oxford University Press (4th Edition), 2013.

CP 219 (AUG) 3 : 1

Machine Learning for Cyber-Physical and Mobility Systems

Data types (spatio-temporal data, event data, trajectories, time-series, point-reference etc.), data pre-processing (filtering, discretization, standardization, transformation, Imputation etc.), Regression (linear regression), Classification (logistic regression, Bayesian classification, SVM, Ensembles), Perceptron and ANN, Clustering (k-means, Spectral Clustering, GMM+EM, Hierarchical Clustering), Dimension Reductions (PCA, Manifold Learning MDS, t-SNE), Anomaly/Outlier Detection Techniques , Semi-supervised Learning, Active Learning

Punit Rathore

Pre-requistes :

Basic of Linear Algebra and Probability, Some programming experience
References : References
Pattern Recognition and Machine Learning, Christopher Bishop, New York, Springer, 2006
Learning from Data. Concepts, Theory, and Methods, by Vladimir Cherkassky, Filip Mulier, 2nd Edition, John Wiley and sons Inc., 2007.

CP 322 (AUG) 2 : 1

Robot Manipulation

Class/Theory Content:
This proposed course introduces the fundamental algorithmic approaches for creating robot systems that can autonomously manipulate physical objects in unstructured environments such as homes and healthcare. Topics include perception (including approaches based on deep learning and approaches based on 3D geometry), grasping, planning (robot kinematics and trajectory generation, collision-free motion planning, task-and-motion planning, and planning under uncertainty), as well as dynamics and control (both model-based and learning-based) for robotic manipulation.

Lab Content:
Lab / Hands-on sessions will guide students through building a software stack in simulator/real robot that will enable a robotic arm to autonomously manipulate objects in cluttered scenes (like a kitchen). The lab provide crucial hands-on experience, directly bridging the gap between theoretical concepts in robot manipulation and their practical implementation. This applied learning, including building a software stack, is fundamental for students to develop critical problem-solving skills and gain the necessary foundation and practical expertise to undertake ambitious and meaningful final projects, whether in simulation or on hardware.

Final Project:
A final project will allow students to dig deeper into a specific aspect of their choosing. The class has hardware available for ambitious final projects, but will also make heavy use of simulation using cloud resources.

Ravi Prakash

Pre-requistes :
Basic linear algebra, probability and algorithms. A basic understanding of neural networks. Coding exposure in Python using
References : Textbooks/References

1. Owen, Tony. "Introduction to Robotics: Mechanics and Control by John J. Craig Addison-Wesley Publishing Company, Massachusetts,

CP 270 (AUG) 3 : 0

Multi-Agent Systems, Control and Learning

Intro to graph theory; Consensus dynamics and its various applications; Social networks, opinion dynamics, social choice theory; Distributed optimization, federated learning; Intro to game theory, network games, population games, population dynamics, game dynamics and learning in games, mechanism design; Intro to multi agent reinforcement learning; Graph neural networks; Applications in distributed control and computing, robotics, transportation systems, power systems, economics, biology and ecology.

Pavankumar Tallapragada

Pre-requistes :
Instructor's permission

References : Mesbahi, Mehran, and Magnus Egerstedt "Graph theoretic methods in multiagent networks"; Shoham, Yoav, and Kevin Leyton-Brown "Multiagent systems: Algorithmic, game-theoretic, and logical foundations"; Narahari, Yadati "Game theory and mechanism design"; Sandholm, William H "Population games and evolutionary dynamics"; Current literature

Transportation and Urban Planning

Preface

SL 221 (AUG) 3 : 1

Introduction to Multi-Modal Mobility Systems

Designing a transportation system; modes of transportation; characteristics of user, vehicle, and road; traffic engineering studies; geometric design principles; traffic analysis; transportation planning; transportation safety; fundamentals of traffic flow; traffic control basics; capacity and level of service; multi-scale modeling; sustainable transportation systems; public transit; freight transportation; multi-modal transportation; intelligent transportation systems; and smart cities.

Vijay Gopal Kovvali

Pre-requisites :

Basic analytical skills

References : • Garber, N.J. and Hoel, L.A. (2014). Traffic and Highway Engineering.
• Roess, R. P., Prassas, E. S., and McShane, W. R. (2019). Traffic Engineering.
• AASHTO (2011) A Policy on Geometric Design of Highways and Streets.

SL 222 (AUG) 3 : 1

Transportation Demand and Supply Modeling

Travel demand-supply interactions and equilibrium; Aggregate modelling methods for travel demand analysis (generation, spatial and temporal distribution, and modal split of travel); Statistical and econometric methods for transportation data analysis; Discrete choice models for travel behaviour analysis; Agent-based methods for travel demand analysis; Traffic assignment in transportation networks; Basics of Convex optimization; Shortest path algorithms; Wardrop user equilibrium; System optimum; Link-based algorithms and their implementation.

Abdul Rawoof Pinjari

Pre-requisites : None

References : (1) J. de D. Ortuzar and L.G. Willumsen, Modelling Transport (4th edition), John Wiley and Sons, 2011.
(2) F. Koppelman and C.R. Bhat. A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.
(3) Boyles, S. D., Lownes, N. E., & Unnikrishnan, A. (2020). Transportation network analysis. Vol. I: Static and Dynamic Traffic Assignment.

SL 201 (AUG) 1 : 0

Seminar in Mobility Systems

Seminars by visitors and students in the program on topics related to mobility systems, logistics, and urban analytics.

Abdul Rawoof Pinjari

Pre-requisites : None

References : Assigned readings

SL 225 (AUG) 3 : 1

Logistics and Freight Modeling

Introduction to freight and logistics systems; Introduction to mathematical modelling; Integer Programming; TSP and VRP; Matching and scheduling problems; Location problems; Heuristics; Collaborative logistics; Inventory modelling; Supply chains; Planning under Uncertainty; Revenue management; Freight movement analysis; Demand estimation and forecasting.

Tarun Rambha

Pre-requisites :

Introductory course on optimization, which covers linear

References : Cachon, G., & Terwiesch, C. (2008). Matching supply with demand (Vol. 20012). New York: McGraw-Hill Publishing.
Applegate, D. L. (2006). The traveling salesman problem: a computational study (Vol. 17). Princeton University Press.
Wolsey, L. A. (2020). Integer programming. John Wiley & Sons.

SL 299A (AUG) 0 : 7

Dissertation Project A

Part A of the final-year MTech dissertation project

Tarun Rambha

Pre-requisites : None

References : As suggested by the project advisor

Division of Mechanical Sciences

Preface

The Division of Mechanical Sciences consists of the departments of Aerospace Engineering, Atmospheric and Oceanic Sciences, Civil Engineering, Chemical Engineering, Divecha Centre for Climate Change, Earth Sciences, Mechanical Engineering, Materials Engineering, Product Design and Manufacturing, and Sustainable Technology. It also maintains an Advanced Facility for Microscopy and Microanalysis (AFMM) and manages the Space Technology Cell (STC). The courses offered in different departments of the Division have been reorganized after review and revision. These are identified by the following codes.

AE	Aerospace Engineering
AS	Atmospheric and Oceanic Sciences
CE	Civil Engineering
CH	Chemical Engineering
DC	Divecha Centre of Climate Change
ER	Earth Sciences
ME	Mechanical Engineering
MT	Materials Engineering
PD	Product Design and Manufacturing
ST	Sustainable Technologies

The first two letters of the course number indicate the departmental code. All the departments and centres (except the Space Technology Cell) of the Division provide facilities for research work leading to the degrees of MTech (Research) and PhD. There are specific requirements for completing a Research Training Programme (RTP) for students registered for research at the Institute. For individual requirements, students are advised to consult the Departmental Curriculum Committee (DCC). MTech Degree Programmes are offered in all the above departments except in the Centre for Product Design and Manufacturing, which offers Master of Design (MDes). Most of the courses are offered by the faculty members of the Division, but instruction by specialists in the field and experts from industries is arranged in certain topics. Student feedback is important to maintain quality, breadth, and depth in courses. Hence, students are urged to actively participate in providing feedback after the completion of each course. Written comments are especially encouraged from the students in addition to marking the scores.

Prof. G. K. Ananthasuresh

Dean

Division of Mechanical Sciences

Aerospace Engineering

Preface

AE 202 (AUG) 3 : 0

Fluid Dynamics

Properties of fluids, kinematics of fluid motion, conservation laws of mass,momentum and energy, potential flows, inviscid flows, vortex dynamics,dimensional analysis, principles of aerodynamics, introduction to laminar viscous flows.

Rishita Das

Pre-requistes : None

References : Kundu, P.K., Cohen, I.M. and Dowling, D.R., Fluid Mechanics, Academic Press,2016.~Fay, J.A., Introduction to Fluid Mechanics, Prentice Hall of India, 1996.~Gupta, V. and Gupta, S.K., Fluid Mechanics and its Applications, Wiley Eastern, 1984~Kuethe, A.M. and Chou, S.H., Foundations of Aerodynamics, Wiley,1972

AE 203 (AUG) 3 : 0

Mechanics and Thermodynamics of Propulsion

Classical thermodynamics, conservation equations for systems and control volumes, one dimensional flow of a compressible perfect gas -isentropic and non-isentropic flows. Propulsion system performance, the gas generator Brayton cycle, zero dimensional analysis of ideal ramjet, turbojet and turbofan cycles, non-ideality and isentropic efficiencies. Performance analysis of inlets and nozzles, gas turbine combustors, compressors and turbines and discussion of factors limiting performance. Chemical rockets - thrust equation, specific impulse, distinction between solid and liquid rockets, maximum height gained analysis, multi-staging, characteristics of propellants.

Sivakumar D

Pre-requistes : None

References : Philip G. Hill and Carl R. Peterson. "Mechanics and thermodynamics of propulsion." Reading, MA, Addison-Wesley Publishing Co., 1992~Nicholas Cumpsty and Andrew Heyes, Jet propulsion. Cambridge University Press, 2015.~Jack D. Mattingly, Elements of gas turbine propulsion. McGraw-Hill, 1996.

AE 205 (AUG) 3 : 0

Navigation, Guidance and Control

Navigation: Continuous waves and frequency modulated radars, MTI and Doppler radars; Hyperbolic navigation systems: INS, GPS, SLAM; Guidance: Guided missiles, guidance laws: pursuit, LOS and PN laws, Guidance of UAVs; Control: Linear time invariant systems, transfer functions and state space modeling,analysis and synthesis of linear control systems, applications to aerospace engineering.

Radhakant Padhi

Pre-requistes : None

References : AE NGC Faculty, Lecture Notes.~Skolnik, M. I., Introduction to Radar Systems,2 nd edition, McGraw Hill Book Company~Bose A., Bhat, K. N., Kurian T.,Fundamentals of Navigation and Inertial Sensors, 1st edition, Prentice-Hall India.~Noureldin, A., Karamat, T. B.,and Georgy, J., Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration, 1st edition ,

AE 211 (AUG) 3 : 0

Mathematical Methods of Aerospace Engineers

Ordinary differential equations; Elementary numerical methods; Finite differences; Topics in linear algebra; Partial differential equations.

Ramesh O N

Pre-requistes : None

References : Erwin Kreysig, Advanced Engineering Mathematics Wiley 2015.

AE 228 (AUG) 2 : 1

Computation of Viscous Flows

Review of schemes for Euler equations, structured and unstructured mesh calculations, reconstruction procedure, convergence acceleration devices,schemes for viscous flow discretization, positivity, turbulence model implementation for unstructured mesh calculations, computation of incompressible flows. Introduction to LES and DNS.

Balakrishnan N

Pre-requistes : None

References : None

AE 255 (AUG) 3 : 0

Aeroelasticity

Effect of wing flexibility on lift distribution; Torsional wing divergence; Vibration of single, two, and multi-degree of freedom models of wing with control surfaces; Unsteady aerodynamics of oscillating airfoil; Bending-torsion flutter of wing; Gust response of an aeroelastic airplane;Aeroservoelasticity of wing with control surfaces.

Kartik Venkatraman

Pre-requistes : None

References : Wright, J.R., and Cooper, J.E., Introduction to Aircraft Aeroelasticity and Loads, John Wiley, 2008.~Hodges, D.H., and Alvin Pierce, G., Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002.~Fung, Y.C., An Introduction to the Theory of Aeroelasticity, Dover edition, 2002.~Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Dover edition, 1996.

AE 261 (AUG) 3 : 0

Structural Vibration Control

Introduction to modal testing and applications, Frequency Response Function (FRF) measurement, properties of FRF data for SDOF and MDOF systems, signal and system analysis, modal analysis of rotating structures; exciters, sensors application in modal parameter (natural frequency, damping and mode shape)estimation. Vibration standards for human and machines, calibration and sensitivity analysis in modal testing, modal parameter estimation methods,global modal analysis methods in time and frequency domain, derivation of mathematical models– modal model, response model and spatial models. Coupled and modified structure analysis. Application of modal analysis to practical structures and condition health monitoring. Introduction to vibration control, passive and active vibration control. Concept of vibration isolation, dynamic vibration absorber, visco- elastic polymers as constrained and unconstrained configuration in passive vibration control. Constitutive modeling of structures with PZ

Siddanagouda Kandagal

Pre-requistes : None

References : Ewins, D.J., Modal analysis: Theory and Practice, Research Studies Press Ltd., England, 2000.~Clarence W. de Silva, Vibration: Fundamentals and Practice, CRC press New York, 1999~G. McConnel, Vibration testing: Theory and Practice, John Wiley & Sons, Inc., New York, 1995. Nashif, D.N., Jones, D.I.G., and Henderson, J.P., Vibration damping, John Wiley, New York,

AE 296 (AUG) 0 : 1

Experimental Techniques in Aerospace Engineering

Experimental techniques in aerospace engineering is a 0:1 credit course that will include demonstrations of experiments in the major sub-disciplines of aerospace engineering. The intent of this course is to give an overview of the experimental facilities and techniques that are commonly used in research in aerospace.

Siddanagouda Kandagal

Pre-requistes : None

References : None

AE 204A (AUG) 3 : 0

Mechanics of Flight Vehicle Structures

Solid mechanics: Vector and tensor algebra, kinematics of deformation, balance laws, constitutive equations; Torsion of circular, non-circular, and thin-walled cross-sections; Bending of thin-walled open and closed section beams, Flexural shear flow; Bending of thin plates, bending and twisting of thin plates; bending and in-plane loading of thin plates; Euler buckling of columns, flexure-torsion buckling of columns, buckling of thin plates; Flight vehicle materials; Structural components of flight vehicles and spacecraft; Loads on flight vehicles and V-N diagram.

Vivekanand Dabade

Pre-requistes : None

References : Morton E. Gurtin. Introduction to Continuum Mechanics. Academic Press. 1981. P. Chadwick. Continuum Mechanics: Concise Theory and Practise. Dover Publications. 1999. T.H.G. Megson. Aircraft Structures for Engineering Students. Elsevier. 2022. David W.A. Rees. Mechanics of Solids and Structures. Imperial College Press. 2000.

AE 223A (AUG) 3 : 0

Hypersonic Aerothermodynamics

Characteristic Features of Hypersonic Flow; Hypersonic Aerodynamics: Inviscid flows – Mach Number Independence Principle, Newtonian Techniques, Tangent Wedge and Tangent Cone, Small Perturbation Analysis, Blast Wave Analogy; Hypersonic Aerothermodynamics – High Temperature Gasdynamics: Shocks and Expansions in thermally perfect and chemicaly reacting flows – equilibrium and non-equilibrium considerations; Compressible Boundary Layers and Aerodynamic Heating; Shock Wave Boundary Layer Interactions; Shock-Shock Interactions; Hypersonic Ground Test Facilities; Design Considerations for Hypersonic Flight Systems

Srisha Rao M V

Pre-requistes :
Fluid Dynamics
Gas dynamics

References :
Hypersonic Aerothermodynamics, John J Bertin
Hypersonic and High-Temperature Gasdynamics, John D Anderson
Hypersonic Flow Theory, Hayes, W.D. and Problein, R.F.

Atmospheric and Oceanic Sciences

Preface

AS 203 (AUG) 3 : 0

Atmospheric Thermodynamics

Vertical structure and composition of the atmosphere, kinetic theory of gases,first and second principles of thermodynamics, thermodynamics of dry air,concept of saturation vapour pressure, water vapour in the atmosphere,properties of moist air, isobaric and isothermal processes, atmospheric stability, parcel and area methods, nucleation, effect of aerosols, clouds and precipitation, forms of atmospheric convection.

Arindam Chakraborty

Pre-requistes : None

References : Iribarne, I.V., and Godson, W.I., Atmospheric Thermodynamics, 2nd Edn, D Reidel Publishing Company, 1971,Rogers, R.R., A Short Course in Cloud Physics,2nd Edition, Pergamon Press, 1979,Bohren, C.F., and Albhecht, B.A.,Atmospheric Thermodynamics, Oxford University Press, 1998,Tsonis, A.A., An Introduction to Atmospheric Thermodynamics, Cambridge University Press, 2002,Wallace,

AS 207 (AUG) 3 : 0

Introduction to Atmospheric Dynamics

Jai Suhas Sukhatme

Pre-requistes : None

References : None

AS 216 (AUG) 3 : 0

Introduction to climate system

Equations of motion for the atmosphere and oceans, observed mean state of theatmosphere and oceans, exchange of momentum, energy and water between the atmosphere and surface, angular momentum cycle, global water cycle, radiation,energetics, entropy in climate system, climate variability, The global carbon cycle, Climate System Feedbacks

Govindasamy Bala

Pre-requistes : None

References : J. Peixoto and A.H. Oort,Physics of Climate,,American Institute of Physics

AS 215 (AUG) 3 : 0

Environmental Fluid Dynamics

An overview of the field of fluid mechanics and description of the physics governing fluid flow. Principles of buoyancy-driven flow: Free-surface flows, gravity currents, stratified flows, gravity waves. Heat transfer and fluid instability: Convection, turbulence, and mixing. The course has four major components: (i) Waves in fluids: interfacial waves and internal gravity waves. (ii) Vertical flows: turbulent plumes, filling box, double-diffusive convection. (iii) Horizontal flows: shallow water approximation, single-layer hydraulics, gravity currents, two-layer flows, and (iv) Turbulent mixing: mixing across very stable interfaces and turbulent convection. The course consists of Lectures, tutorials, and simple laboratory experiments.

Bishakhdatta Gayen

Pre-requistes : None

References : Fluid Mechanics 3rd Edition: Authors: Ira Cohen and Pijush Kundu: Academic Press, Published Date: 2004~Buoyancy Driven Flow: Authors: J. S. Turner: Cambridge University Press, Published Date: 1979~Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics: Authours: J. Pedlosky, Spriger Verlag, Published Date: 2003

Earth Sciences

Preface

ES 202 (AUG) 3 : 0

Biogeochemistry

Prosenjit Ghosh

Pre-requistes : None

References : None

ES 204 (AUG) 3 : 0

Origin and Evolution of the Earth

Big Bang; origin of elements; early solar system objects; bulk Earth composition; comparison of Earth and other Solar System objects; core- mantle differentiation; composition of the terrestrial mantle; mantle melting and geochemical variability of magmas; major, trace element and radiogenic isotope geochemistry; redox evolution of the mantle; evolution of the atmosphere and biosphere.

Ramananda Chakrabarti

Pre-requistes : None

References : Charles H. Langmuir and Wally Broecker, How to build a habitable planet, Revised and expanded edition, Princeton University Press, 2012;~A. P. Dickin, Radiogenic Isotope Geology, Cambridge University Press, 1995;~John D. Winter, Principles of Igneous and Metamorphic Petrology, 2nd edition, Pearson Prentice Hall, 2010,

ES 205 (AUG) 3 : 0

Mathematics for Geophysicists

Vector fields: basic vector algebra, line, surface and volume integrals, potential, conservative fields, gradient, divergence, curl, circulation, Stokes's theorem, Gauss's theorem, applications in fluid mechanics and electromagnetism, Kelvin's theorem, Helmholtz's theorem. Linear algebra: Matrices, operations, eigen components, systems of linear differential equations, examples. Partial differential equations: The diffusion equation,wave equation, Laplace's equation, Poisson's equation, similarity solutions,numerical solutions (simple examples with MATLAB), series solutions, spherical harmonic expansions. Dimensional analysis: Pi theorem, similarity,nondimensional formulation of geophysical problems, examples.

Binod Sreenivasan

Pre-requistes : None

References : Riley, K.F., Hobson, M.P., and Bence, S.J., Mathematical methods for physics and engineering, Cambridge University Press, 2006.~Panton, R.L., Incompressible flows, John Wiley & Sons, 2006~Albarede, F., Introduction to geochemical modelling, Cambridge University Press, 1996~Lecture notes

ES 215 (AUG) 3 : 0

Introduction to Chemical Oceanography

The concentration, isotopic composition, and distribution of the dissolved and particulate components of seawater tells the story of a fascinating and complex interplay between tectonic uplift, chemical and physical weathering, climate, biology, ocean circulation, and intrinsic properties of elements and ions in solution. In this series of lectures we will try to understand what controls the chemistry of seawater from a regional to global scale and what is the interplay between climate and ocean chemistry. The major themes that will be covered are: (a) concentration, spacio-temporal distribution, and the residence time ofthe dissolved components of seawater; (b) air–sea exchange of gases; (c) steady state and non-steady state oceanic cycle of dissolved components; (d) estimation of oceanic mixing time utilising natural and artificial tracers; (e) influence of biology on ocean chemistry - carbon pumping from surface to deep; (f) the role deep ocean carbon reservoir in controlling clim

Sambuddha Misra

Pre-requistes : None

References : Tracers in the Sea - Broecker and Peng, LDGEO Press, 1983~An Introduction to the Chemistry of the Sea - Michael E. Q. Pilson, Cambri dge University Press

ES 218 (AUG) 3 : 0

Introduction to Seismology

This course is divided into three parts. It starts with an introduction to the dynamics of diverse seismic sources, e.g., volcanic, tectonic, glacial, fluvial, oceanic, atmospheric and artificial processes, which routinely shake the subsurface. The second part will present the following key topics in elastodynamics that guide the propagation of the waves originating from these seismic sources: types of elastic waves from a point dislocation sources; ray theory, travel-time function in layered media, turning points; plane waves in a homogenous medium and at interfaces; Snell’s law; Earth’s anisotropy; shear-wave splitting; seismic attenuation; surface-wave propagation and dispersion; free oscillations of the Earth. The final part connects the first two and introduces methods that not only help us infer the Earth’s structure but also study the source physics from the seismic measurements. Some motivating examples pertaining to the concepts discussed in this part include: 1. ground-moti

Pawan Bharadwaj Pisupati

Pre-requistes : None

References : Aki, Keiiti, and Paul G. Richards. Quantitative seismology. Chapman, Chris. Fundamentals of seismic wave propagation. Shearer, Peter M. Introduction to seismology.

ES 220 (AUG) 3 : 0

Introduction to satellite Geodesy

Short history of Geodesy: definition of Geodesy, First attempts at measuring Earth, developments in the 20th century, Modern Geodetictools Gravitation: Newtons law, potential theory, Laplace’s equation Solid Earth: visco-elastic Earth, Loading and deformations, Load love numbers, gravimetry Geodetic sensors in the orbit: GNSS,Altimeters, GRACE Climate change indicators and theirrelation to Geodesy: sea level rise, ice-sheet mass loss, polar motion.

Bramha Dutt Vishwakarma

Pre-requistes : None

References : 1.Heiskanen, W. A., and Moritz, H., “Physical Geodesy”, San Francisco, WH Freeman. 2.William, K. M., Theory of Satellite Geodesy: Applications of Satellites to Geodesy, Dover Earth Science. 3.Torge, W., Geodesy, De Gruyter Textbook.

Sustainable Technologies

Preface

ST 214 (AUG) 3 : 0

Mathematical Analysis of Experimental Data

Design of Experiments, Data types and data gathering tools. Errors, systematic & random errors, methods to minimize them, and account for them. Measurement variability. Instrument calibration and corrections at different scales. Significant figures. Uncertainty analysis and curve fitting; Data analysis of data distribution, normal, Chi-squared and t- distribution, confidence interval and hypothesis testing. Design of experiments: replication, randomization, blocking and controls. ANOVA, Single factor experiments, randomized blocks, Latin square designs, factorial and fractional factorial designs. Simple and multiple linear regressions. Mathematical analysis of experimental data from problems in fluid flow, heat transfer and combustion.

Lakshminarayana Rao M P

Pre-requistes : None

References : Douglas C. Montgomery, Design and Analysis of Experiments (2012), John Wiley and Sons, Inc.~Box, G. E. P., Hunter, W. G., and Hunter, J. S.(1978),Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building, John Wiley & Sons. Inc. ISBN: 0-471 09315-7.

ST 213 (AUG) 3 : 0

Turbo machines in Renewable Energy

The objectives of the course is to refine turbo machinery designs in challenging operating conditions imposed by renewable energy sources characterized by variability(input/outputsides)and low intensity/enthalpy levels.concepts include Euler theory,velocity traingles,dimensional analysis, meanline/streamline theory,loss models,performance estimation,Cordier/nsds diagrams and others.Practical design approach from theory and experimental modules for incompressible fluids(hydro turbines, wind turbines,and liquid pumps)and compressible fluids (air,steam,and new working fluids for solar thermal and waste heat sources)Radial,diagonal and axial flow turbo machines with impulse and reaction physics.Discussion on innovative and unconventional turbo machines.

Punit Singh

Pre-requistes : None

References : DixonS.L and HallC.A, Fluid Mechanics and Thermo Dynamics of Turbomachinery, 6th Edition,Elsevier,publication 2010,~Neschleba M, Hydraulic turbines-Their design and equipment , Atria Prage,1957,~StepanoffA.J,Centrifugal and Axial Flow Pumps,JohnWiley & Sons,Inc.,1957,~Horlock J.H,Axial Flow Compressors and Axial Flow Turbines,Fluid Mechanics and

ST 217 (AUG) 3 : 1

Field hydrology, river engineering and basin studies

Dimensional Analysis: Buckingham pi theorem, non-dimensional groups, physical similarity, functionalities, scaling (with single and multiple independent groups), intermediate asymptotics; Probability: history, gaming, origin of random number, Bernoulli trials, binomial theorem, normal distribution; Curve fitting: regression and theory of splines; Classical Statistics: origin, Galton table- Darwinism; Karl Pearson: large sample studies, Pearson type distribution curves, Chi-square variance and limitations; William Gosset: small sample study, probable error of means, correlation coefficient, z statistics, Barley experiments, Fischer: degree of freedom, z to t statistics for small samples, Rothamsted agricultural experiments, analysis of variance, fundamentals of experimental designs, maximum likelihood, inductive reasoning; Uncertainty Analysis: Moffat's single sample theory in experiments; Engineering and Science problems: (hydrology, hydropower, turbomachinery, biology, chemistry, macroeco

Punit Singh

Pre-requistes : None

References : [1] Barenblatt. G. I, 'Scaling', Cambridge Texts in Applied Mathematics, (2003) [2] Holman J. P., Experimental Methods for Engineers, Mcgraw-Hill Series in Mechanical Engineering, Eight Edition, (2011) [3] Grinstead M. C., Snell L. J., 'Introduction to Probability', 'American Mathematical Society', (1991) [4]Moffat, R. J., 'Contributions to the Theory of Single-Sample Uncertainty Analysis', J. Fluids

ST 221 (AUG) 3 : 0

Concrete Technology: fundamentals and sustainable practices

This module aims to provide students with fundamental knowledge in the area of cement hydration, sustainable mineral admixtures and chemical admixtures, and their influence on fresh and hardened stage of cement-based materials. It also provides students with in-depth knowledge in concrete durability, mechanical properties and time- dependent deformations. The module discusses the basic considerations and design philosophy for performance-based design and production of sustainable concrete. The students will also learn about the progress in concrete technology and the latest development in high-strength, high-performance concrete, lightweight concrete, and self-healing concrete. Sustainable development in construction industry including application of recycled aggregates, bio-based admixtures and low-carbon concrete would be discussed as well. The module would be taught through interactive lecture sessions, exercises, problem-based learning approach and site visits.

Souradeep Gupta

Pre-requistes : None

References : 1. Concrete, by David Darwin, J. Francis Young, and Sidney Mindess. Publisher: Pearson. 2. Properties of concrete, 5th edition, by A.M. Neville. Publisher: Pearson.

ST 226 (AUG) 3 : 0

Sustainable Water Management

Water cycle, renewable water. Freshwater resources: surface water, ground water. Water usage, stress & scarcity. Water smart agriculture. Rainwater harvesting. Surface, ground & rainwater quality. Contamination scenarios & need for treatment. Drinking water treatment & requirements. Other remediation techniques. Industrial water treatment & requirements. Seawater desalination. Wastewater quantity & quality, parameters. Water pollution, hazards & need for wastewater treatment. Conventional wastewater treatment. Resource recovery options. Recycling of treated wastewater. Options for industrial wastewater treatment.

Punit Singh , Sreenivasan Ramaswami , Yagnaseni Roy

Pre-requistes : None

References : Wastewater engineering: Treatment and reuse, 4th edi?on.Editors: George Tchobanoglous; Franklin L. Burton; H. David Stensel. Publisher: McGraw-Hill. Separa?onProcess Principles, 3rd edi?onErnest J. Henley, J. D. Seader, D. Keith Roper. Publisher: Wiley. Lecture notes and slides

ST 225 (AUG) 3 : 0

Sustainable Materials

The “Sustainable Materials” course offers a comprehensive understanding of key materials, emphasizing their environmental impact and sustainable practices. It explores eco-friendly material creation using renewable resources, starting with the need for sustainable materials and the environmental issues with current materials. The course covers renewable resources like lignocellulosic biomass, plastic waste, and CO2, teaching various conversion and synthesis techniques (biological, chemical, thermal, etc.). Students will learn about the properties and industrial applications of sustainable materials, including carbonaceous materials (graphene, nanotubes, etc.), polymers (new class and dropins), fuel components, surfactants, pharmaceuticals, etc. The aim is to teach students the skills to develop and apply sustainable materials for a greener future.

Navneet Kumar Gupta

Pre-requistes : None

References : V. Popa and I. Volf Biomass as Renewable Raw Material to Obtain Bioproducts of High-Tech Value, Elsevier B.V., 2018. https://doi.org/10.1016/C2015-0-05810-5

ST 224 (AUG) 3 : 0

Renewable energy

Renewable energy holds promise for a cleaner future. This module will explore various renewable energy sources such as solar, wind, geothermal, wave, thermo-chemical, and bio-chemical methods, with a specific emphasis on technological advancements. Special attention will be given to the production of hydrogen and high-energy molecules through thermo-chemical conversion. Additionally, it will cover biomass and municipal solid waste (MSW) as significant carbon/hydrogen resources, examining their transformation into valuable chemicals and fuels using innovative processes such as pyrolysis, gasification, and thermo/bio-chemical conversion. By integrating emerging chemocatalytic methods, these advancements aim to improve energy generation with sustainable alternatives that minimize waste and carbon emissions.

Lakshminarayana Rao M P

Pre-requistes : None

References : M. Kanoglu, Y. A. Cengel, J. M. Cimbala Fundamentals and Applications of Renewable Energy 2019 McGraw-Hill Education ISBN: 978-1260455304 W. D. Jong, J. R. V. Ommen Biomass as a Sustainable Energy Source for the Future: Fundamentals of Conversion Processes American Institute of Chemical Engineers, Inc. 2014 DOI:10.1002/9781118916643. G. W. Huber, S. Iborra, A. Corma Chem.

Chemical Engineering

Preface

CH 201 (AUG) 3 : 0

Engineering Mathematics

Linear algebraic equations, linear operators, vector and function spaces,metric and normed spaces, existence and uniqueness of solutions. Eigen values and eigen vectors/functions. Similarity transformations, Jordan forms,application to linear ODEs, Sturm-Liouville problems. PDE's and their classification, initial and boundary value problems, separation of variables,similarity solutions. Series solutions of linear ODEs. Elemetary perturbation theory. References:

Prabhu R Nott , Ananth Govind Rajan

Pre-requistes : None

References : Linear Algebra and its Applications,Gilbert Strang,Thompson (Indian edition).~Mathematical Methods for Physicists,J. B. Arfken and H. J. Weber (7th edition, Indian reprint, 2017).~Mathematical Methods in Chemical Engineering, S.Pushpavanam, Prentice-Hall India (2005). ~Advanced Mathematical Methods for Scientists and Engineers, C. M. Bender and S. A. Orszag, McGraw-Hill/Springer-Verlag

CH 202 (AUG) 3 : 0

Numerical Methods

Basics of scientific computing, basics of Matlab programming, solutions of linear algebraic equations, eigenvalues and eigenvectors of matrices, solutions of nonlinear algebraic equations, Newton-Raphson methods, function approximation, interpolation, numerical differentiation and integration,solutions of ordinary differential equations – initial and boundary value problems, solutions of partial differential equations, finite difference methods, orthogonal collocation.

Bhushan J Toley , Debashis Roy

Pre-requistes : None

References : Gupta S.K., Numerical Methods for Engineers, New Age International Publishers,3rd edition, 2015~Chapra, S.C. and Canale, R.P., Numerical Methods for Engineers, McGraw Hill, NY, 6th edition, 2010~Beers, K.J., Numerical Methods for Chemical Engineering, Cambridge Univ. Press, Cambridge, UK 2010

CH 203 (AUG) 3 : 0

Transport Processes

Dimensional analysis and empirical correlations. Molecular origins of diffusion. Steady/unsteady shell balances in one/two dimensions. Solution of unsteady diffusion equation by similarity transform and separation of variables. Conservation laws and constitutive relations in three dimensions. Diffusion dominated transport. Fluid flow due to pressure gradients. Boundary layer theory for transport in forced convection. Natural convection.References:

Kumaran V

Pre-requistes : None

References : Bird, R.B, Stewart, W.E. and Lightfoot, E.N., Transport Phenomena, Wiley, 1994.~L. G. Leal, Luminar Flow and Convective Transport Processes, Butterworth Heineman, 1992.

CH 204 (AUG) 3 : 0

Thermodynamics

Classical thermodynamics: first and second laws, Legendre transforms, properties of pure substances and mixtures, equilibrium and stability, phase rule, phase diagrams, and equations of state, calculation of VLE and LLE, reaction equilibria, introduction to statistical thermodynamics.

Sudeep Neelakantan Punnathanam

Pre-requistes : None

References : Tester,J. W.,and Modell, M., Thermodynamics and its Applications

CH 206 (AUG) 1 : 0

Seminar Course

The course aims to help students in preparing, presenting and participating in seminars. The students will give seminars on topics chosen in consultation with the faculty.

Rahul Roy

Pre-requistes : None

References : None

CH 242 (AUG) 3 : 0

Special Topics in Theoretical Biology

Motivation for theoretical studies of biological phenomena; Epidemiology, spatio-temporal disease spread, vaccination and other interventions; Population dynamics, predator-prey systems, microbiomes; Viral dynamics, within-host models, HIV, SARS-CoV-2; Drug pharmacokinetics and therapy, compartmental models; Molecular evolution and phylogenetics, antimicrobial resistance; Biological networks, cell signalling and fate decisions; Immune responses, innate and adaptive responses, vaccination and other immunomodulation strategies; Cancer and aging; Examples will illustrate deterministic, stochastic, and data-driven modeling approaches

Narendra M Dixit

Pre-requistes : None

References : 1. J. D. Murray, Mathematical biology I & II, Springer, 2003 (3rd edition)
2. K. Raman, An introduction to computational systems biology, CRC, 2021
3. U. Alon, An introduction to systems biology, CRC, 2020

CH 241 (AUG) 3 : 0

Nanotechnology

CH241 Nanotechnology (3:0)
Introduction to Chemical Engineering Perspective of Nanotechnology, Physics and Chemistry at the nanoscale, Overview of Characterization methods, Overview of Fabrication techniques, Functional nanostructured materials, Critical review of current applications of nanotechnology in catalysis for energy transition

Venugopal S

Pre-requistes :
Bachelors Degree in Chemical Engineering

References : G. Timp (Ed.), Nanotechnology, Springer International Edition, 2005.

J. Lambauer, A. Voss, and U. Fahl, Nanotechnology and Energy-

CH 255 (AUG) 3 : 0

Introduction to Polymer Science

Introduction: polymer microstructure, types of polymers, molar mass distribution and measurement; Ideal chain: flexibility mechanism, conformation of an ideal chain, ideal chain model, radius of gyration, distribution of end-to-end vector, scaling argument, pair correlation of ideal chain; Real polymer chain: excluded volume and self-avoiding walk, effect of solvent, deforming real and ideal chain, temperature effect on real chain, adsorption of a single chain, distribution of end-to-end distance for real chain; Thermodynamics of mixing: energy and entropy, equilibrium and stability, mixture at low composition, quality of solvent, osmotic pressure, semidilute theta solutions; Random branching without gelation: concepts and definition of gelation, mean field model of gelation, scaling model of gelation; Computer simulation in polymer physics: molecular dynamics, Monte Carlo, random and self-avoiding walk.

Nirmalya Bachhar

Pre-requistes : None

References : 1) Polymer Physics by Michael Rubinstein & Ralph H Colby, Oxford University Press
2) Introduction to Polymer Physics by M Doi & H See, Oxford University Press
3) Polymer Solutions by Iwao Teraoka, John Wiley & Sons

Civil Engineering

Preface

CE 247 (AUG) 3 : 0

Remote Sensing and GIS for Water Resources Engineering

Basic concepts of remote sensing. Airborne and space borne sensors. Digital image processing. Geographic Information System. Applications to rainfall - runoff modeling. Watershed management. Irrigation management. Vegetation monitoring. Drought and flood monitoring, Environment and ecology.Introduction to digital elevation modeling and Global Positioning System (GPS). Use of relevant software for remote sensing and GIS applications.

Nagesh Kumar D

Pre-requistes : None

References :
Remote Sensing and Image Interpretation, T.M. Lillesand and R.W. Kiefer, John Wiley & Sons, 2000.~Remote Sensing - Principles and Interpretation,

CE 201 (AUG) 3 : 0

Basic Geo-mechanics

Introduction to genesis of soils, basic clay mineralogy; Principle of effective stress, permeability and flow; Fundamentals of Tensors, Introductionto stresses and deformation measures; Mohr-Coulomb failure criteria, soil laboratory tests; Critical state and stress paths. Shear Strength and Stiffness of Sands; Consolidation, shear strength and stiffness of clays

Swetha Veeraraghavan

Pre-requistes : None

References : Wood,D.M.,Soil Behaviour and Critical State Soil Mechanics,Cambridge University Press,1991.

CE 204 (AUG) 3 : 0

Solid Mechanics

Introduction to tensor algebra and calculus, indicial notation, matrices of tensor components, change of basis formulae, eigenvalues, Divergence theorem. Elementary measures of strain. Lagrangian and Eulerian description of deformation. Deformation gradient, Polar decomposition theorem, Cauchy-Green and Lagrangian strain tensors. Deformation of lines, areas and volumes. Infinitesimal strains. Infinitesimal strain- displacement relations in cylindrical and spherical coordinates. Compatibility. Tractions, body forces,stress at a point, Cauchy's theorem. Piola-Kirchhoff stress tensors. Momentum balance. Symmetry of the Cauchy stress tensor. St. Venant's Principle. Virtual Work. Green's solids, elastic strain energy, generalized Hooke's Law, material symmetry, isotropic linear elasticity in Cartesian, cylindrical and spherical coordinates, elastic moduli, plane stress, plane strain,. Navier's formulation. Airy stress functions. Selected problems in elasticity. Kirchhoff's uniqueness theor

Ananth Ramaswamy

Pre-requistes : None

References : Fung Y. C. and Pin Tong, Classical and Computational Solid Mechanics, World Scientific, 2001~Boresi, A.P., Chong K., and Lee J., Elasticity in Engineering Mechanics, Wiley, 2010~Theoretical Elasticity, A.E. Green and W. Zerna, 1968,Dover Publications~Malvern L., Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969

CE 211 (AUG) 3 : 0

Mathematics for Engineers

Revision of ordinary linear ODEs, Formal operators, Adjoint operator, Sturm-Liouville theory, eigenvalue problems, Classification of PDEs, Characteristics / first order PDEs, Laplace equation / potential theory, Separation of variables (cartesian, polar), Eigenfunction expansions, Green's functions, Introduction to boundary value problems Probability space and axioms of probability. Conditional probability. Total probability and Bayes theorems. Scalar and vector random variables. Probability distribution and density functions. Expectation operator. Functions of random variables. Vector spaces and subspaces, solution of linear systems, Linear independence,basis, and dimension, The four fundamental subspaces, Linear transformations,Orthogonal vectors and subspaces, Cosines and projections onto lines,Projections and least squares, The fast Fourier transform, Eigenvalues and eigenvectors, Diagonalization of a matrix, Difference equations and powers of matrices, Similarity transformation

J M Chandra Kishen , Debraj Ghosh

Pre-requistes : None

References : Michael Stone,Paul Goldbart,2009,Mathematics for Physics: A Guided Tour for Graduate Students,Cambridge University Press~Probability, Random Variables and Stochastic Processes, A Papoulis and S U Pillai~Linear Algebra and Its Applications by Gilbert Strang

CE 220 (AUG) 3 : 0

Design of Substructures

Design considerations, field tests for bearing capacity and settlement estimates, selection of design parameters. Structural design considerations.Codes of practice. Design of spread footings, combined footings, strap footings, ring footings, rafts, piles and pile caps and piers.

Raghuveer Rao Pallepati

Pre-requistes : None

References : Bowles,J.E. Foundation analysis and design. 5th Edn.,McGraw Hill,1996 ~Indian Standard Codes

CE 221 (AUG) 3 : 0

Earthquake Geotechnical Engineering

Introduction to engineering seismology. Plate tectonics. Earthquake magnitude. Ground motion. Effect of local soil conditions on ground motion. Dynamic behaviour of soils. Analysis of seismic site response. Liquefaction phenomena and analysis of pore pressure development. Laboratory and in-situ testing for seismic loading. Analysis and design of slopes, embankments, foundations and earth retaining structures for seismic loading. Case histories. Mitigation techniques and computer- aided analysis

Gali Madhavi Latha

Pre-requistes : None

References : Geotechnical Earthquake Engineering By Steven L. Kramer, Pearson Education,2003~Geotechnical Earthquake Engineering Handbook, Robert W. Day, McGraw-Hill,2002.~Current Literature

CE 236 (AUG) 3 : 0

Fracture Mechanics

Introduction; Linear Elastic Fracture Mechanics; Design based on LEFM; Elasto-Plastic Fracture Mechanics; Mixed Mode Crack Propagation; Fatigue CrackPropagation; Finite Elements in Fracture Mechanics.

Remalli Vidya Sagar

Pre-requistes : None

References : T. L. Anderson, Fracture Mechanics, CRC press, Fourth Edition, 2017, Boca Raton, Florida~David Broek, Elementary Fracture Mechanics, Sijthoff and Noordhoff, The Netherlands.~Prashanth Kumar, Elements of Fracture Mechanics,Wheeler Publishing, New Delhi.~J. F. Knott, Fundamentals of Fracture Mechanics, Butterworths, London.

CE 249 (AUG) 3 : 0

Water Quality Modeling

Basic characteristics of water quality, stoichiometry and reaction kinetics.Mathematical models of physical systems, completely and incompletely mixed systems. Movement of contaminants in the environment. Water quality modeling in rivers and estuaries - dissolved oxygen and pathogens. Water quality modeling in lakes and ground water systems.

Sekhar M

Pre-requisites : None

References : Chapra,S.C.,Surface Water Quality Modeling,McGraw Hill,1997. ~Tchobanoglous, G., and Schroeder, E.D., Water Quality, Addison Wesley, 1987.

CE 263 (AUG) 3 : 0

Modelling Transport and Traffic

Ashish Verma

Pre-requisites : None

References : None

CE 217 (AUG) 3 : 0

Fluid Mechanics

Vectors and tensors, divergence theorem, pressure, Archimedes principle, fluid mass conservation, heat and contaminant conservation, momentum conservation and Cauchy equation, stress tensor, constitutive relation for Newtonian fluids, Navier-Stokes equations, vorticity, laminar plane couette and open channel flow, Euler equations, potential flow approximation, simple solutions of potential flows, laminar flow in pipes and channels, transition to turbulence Reynolds stress and fluxes, laminar boundary layer, laminar bottom dense flows.

Debsunder Dutta

Pre-requisites : None

References : Kundu, Cohen and Dowling Fluid Mechanics, Sixth Ed., Academic Press, 2016. ~White, F.M. Fluid Mechanics, Eighth Edition, McGraw Hill, 2016.

CE 284 (AUG) 3 : 0

Plates, Shells, and Geometric Elasticity

Brief review of elasticity and variational principles. Classical plate theories: Elements of plate deformation; pure bending of thin circular and rectangular plates under various boundary conditions; Navier and Lévy solutions; introduction to plates of general shapes; problems in combined lateral and membrane loading in thin rectangular and circular plates. Introduction to Mindlin-Reissner shear plates; elements of large deflection of thin plates and the Fóppl-von Kármán equations. Introduction to stability and plate buckling. Applications of plate theories. Brief introduction to the differential geometry of surfaces; First and second fundamental forms; principal curvatures; Gauss curvature. Shell theories: General Kirchhoff-Love linear theory of thin shells; membrane theory of shells for cylindrical shells and shells of revolution; engineering applications. Introduction to computational methods for shell and plate problems. Other topics as time permits (orthotropic plates; plates.

Narayan K Sundaram

Pre-requistes :

Graduate-level solid mechanics (CE 204 / ME 242 or equivalent),

References : (1) Ventsel and Krauthammer, Thin Plates and Shells: Theory, Analysis and Applications (2) Timoshenko and Woinowsky-Krieger, Theory of Plates and Shells (3) Villagio, Mathematical Models for Elastic Structures (4) Historical and current literatur

CE 260 (AUG) 3 : 0

Rock Mechanics

Physical, mechanical and engineering properties of rocks; rock discontinuities; strike; dip; bedding planes; joints; faults; folds; unconformities; geological exploration by bore holes; methods of drilling; rock strength and rock mass strength; rock failure criteria; rock mass classification; rock mass rating, geophysical methods; geology of dam sites and reservoirs; Importance of geology in dam construction; rock slope stability Stresses and strains; theory of elasticity; in-situ stresses; numerical and computer methods in rock mechanics and under-ground excavations.

Jyant Kumar , Tejas Gorur Murthy

Pre-requistes : None

References : 1. Engineering Rock Mechanics. John A. Hudson and John P. Harrison. 2.Fundamentals of Rock Mechanics. John Jaeger, N. G. Cook, and Robert Zimmerman. 3. Introduction to Rock Mechanics. Goodman, R.E. John Wiley & Sons. 4. Rock Mechanics and Rock Engineering. Ömer Aydan.

CE 203A (AUG) 3 : 0

Hydrologic Safety Evaluation of Dams

Significance of hydrologic safety evaluation and modeling, uncertainty in hydro-meteorological processes; Standard project storm and Probable maximum precipitation (PMP); Design flood estimation - Hydro-meteorological approach: unit hydrograph construction, design storm depth estimation from PMP Atlas, storm transposition and adjustment, estimation of loss rate, base flow and time distribution coefficients, HEC-HMS model; Flood frequency analysis approach: At-site and regional frequency analysis using commonly used probability distributions in hydrology, Probability plotting and Goodness of fit tests; Reservoir sedimentation, Reservoir rule curve.

Srinivas V V

Pre-requistes : None

References : Chow, V.T., Maidment, D.R. and Mays, L.W., Applied Hydrology, McGraw-Hill, 1988.
Handbook for Assessing and Managing Reservoir Sedimentation, Dam Safety Rehabilitation Directorate, Central Water Commission, 2019.
Hosking, J. R. M., and Wallis, J. R., Regional Frequency Analysis: An Approach Based on L-Moments, Cambridge University Press, 1997.

CE 207A (AUG) 3 : 0

Characterization of Bituminous Materials

Introduction and overview of mixture design; chemical, physical, and rheological properties of asphalt binder; behavior, testing, and selection of aggregates; design of asphalt mixtures, compaction and properties; common distresses and characterization of distresses; additives and surface properties; engineered materials, warm mixtures, RAP, and other special mixtures.

Satyavati Komaragiri

Pre-requistes :

References : 1) F.L. Roberts, P. S. Kandhal, E.R. Brown, D-Y. Lee and T. W. Kennedy, 2nd Edition, NAPA Research and Education Foundation, 19
2) Dallas N. Little, David H. Allen, and Amit Bhasin. Modeling and design of flexible pavements and materials, Springer, 2018.
3) C. E. G. Justo, S.K. Khanna, and A. Veeraragavan, Highway engineering, Nem Chand & Bros, 2017.

CE 210A (AUG) 3 : 0

Thermodynamic Modelling of Cementitious Systems

A brief recap of cement chemistry, cement hydration and concrete technology (influence of binder chemistry on reaction products, concrete microstructure, mineral and chemical admixtures, microstructure and pore structure; concrete mechanics and durability); A brief recap of thermodynamics (zeroth law, first law, second law, activity); Law of mass action; Mass Balance calculations; Determination of Reactivity; Fundamentals of thermodynamic modelling; Predicting reaction products; Predicting pore solution compositions; Predicting pore volumes; Kinetic modelling; Structure-property relations in concrete.

Keshav Bharadwaj Ravi

Pre-requistes :

Prerequisites: The participants are expected to have basic
References : 1. “Concrete: Microstructure, Properties, and Materials” by P.K. Mehta and Paulo J. M. Monteiro, 4th Edition (2014), McGraw Hill Education (India), New Delhi, India. 2. “Introduction to the Thermodynamics of Materials” by David R. Gaskell and David E. Laughlin, 6th Edition (2018), CRC Press, Boca Raton, FL, USA 3. Online tutorials 4. Recent literature

CE 213A (AUG) 3 : 0

Design for Dynamic and Fatigue Loadings

Introduction to dynamic loading, fatigue loading, vibration concepts, and engineering applications in civil structures; Dynamic response of structures under earthquake, machinery vibration; Principles of dynamic structural design including vibration control, dynamic amplification, response spectrum concepts; Earthquake resistant design concepts of buildings, code-based procedures for analysis and design; Fundamentals of fatigue; stress cycles, S–N curves, fracture mechanics based crack propagation theories, cumulative damage theories. Life predictions and structural integrity.

J M Chandra Kishen

Pre-requistes : None

References : • Chopra A K, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Pearson Education, 2017.
• Agarwal and Shrikhande, Earthquake Resistant Design of Structures, PHI Learning Private Limited, New Delhi, 2006
• Suresh S., Fatigue of Materials, Second Edition, Cambridge University Press, UK.

CE 212A (AUG) 3 : 0

Stochastic dynamics, optimal transport and neural algorithms

This course introduces the mathematical foundations of diffusive stochastic processes and their modern algorithmic extensions. The first part covers Brownian motion, sample-path regularity, stochastic continuity, and the basic structure of Itô processes. It then develops Itô and Stratonovich calculus, with illustrative examples including Langevin dynamics, Ornstein-Uhlenbeck processes, and geometric Brownian motion. The course next treats the Fokker-Planck and Kolmogorov backward equations, together with Feynman-Kac representations, killed diffusions, and boundary-conditioned stochastic processes. A further module is devoted to change of measure for diffusions, including Girsanov’s theorem and Doob’s h-transform, with applications to controlled Brownian motion and related probabilistic constructions. The second part of the course introduces KL-divergence-based variational formulations and then develops the stochastic optimal transport viewpoint, emphasizing diffusive transport and entropic interpolation rather than deterministic Monge transport. The course concludes with selected neural methods built on these ideas, including neural stochastic control, neural filtering, and OT-inspired stochastic optimization schemes for learning systems.

Debasish Roy

Pre-requistes : None

References : 1. B. Øksendal, 2003, Stochastic Differential Equations: An Introduction with Applications, Springer.
2. C. Villani, 2010, Optimal Transport: Old and New, Springer.

Climate Change

Preface

Materials Engineering

Preface

MT 202 (AUG) 3 : 0

Thermodynamics and Kinetics

Classical and statistical thermodynamics, Interstitial and substitutionalsolid solutions, solution models, phase diagrams, stability criteria, critical phenomena, disorder-to-order transformations and ordered alloys, ternary alloys and phase diagrams, Thermodynamics of point defects, surfaces and interfaces. Diffusion, fluid flow and heat transfer.

Sai Gautam Gopalakrishnan

Pre-requistes : None

References : C.H.P. Lupis: Chemical Thermodynamics of Materials, Elsevier Science, 1982~P.Shewmon: Diffusion in Solids, 2nd Edition, Wiley, 1989.~A.W. Adamson and A.P.Gast: Physical Chemistry of Surfaces (Sixth Edition), John Wiley, 1997.

MT 206 (AUG) 3 : 0

Texture and Grain Boundary Engineering

Concepts of texture in materials, their representation by pole figure andorientation distribution functions. Texture measurement by different techniques. Origin and development of texture during material processing stages: solidification, deformation, annealing, phase transformation, coating processes, and thin film deposition. Influence of texture on mechanical and physical properties. Texture control in aluminum industry, automotive grade and electrical steels, magnetic and electronic materials. Introduction to grain boundary engineering and its applications.

Satyam Suwas

Pre-requistes : None

References : M. Hatherly and W. B. Hutchinson, An Introduction to Texture in Metals (Monograph No. 5), The Institute of Metals, London~V. Randle, and O. Engler,Introduction to Texture Analysis: Macrotexture, Microtexture and Orientation mapping, Gordon and Breach Science Publishers~F. J. Humphreys and M. Hatherly,Recrystallization and Related Phenomenon, Pergamon Press~P. E. J.

MT 220 (AUG) 3 : 0

Microstructural Engineering of Structural Materials

Review of crystal defects: dislocation theory, grain boundaries and heterophase boundaries, defect kinetics and defect interactions; Role of microstructure on mechanical properties: strengthening mechanisms, ductilizing mechanisms, toughening mechanisms, effect of microstructure on creep, fatigue and impact resistance; Methods of controlling microstructures: phase transformations (L?S, V?S, S? S), heat treatments, solidification, mechanical processing, texture control, recovery and recrystallization, sintering, etc;Case studies of microstructural control of engineering metals, alloys and ceramics (Ni- base superalloys, YSZ, ceramic-matric composites, Ti-alloys,steels, etc)

Surendra Kumar Makineni

Pre-requistes : None

References : None

MT 231 (AUG) 3 : 0

Interfacial Phenomena in Materials Processing

Ashok M Raichur

Pre-requistes : None

References : None

MT 250 (AUG) 3 : 0

Introduction to Materials Science and Engineering

Subodh Kumar

Pre-requistes : None

References : None

MT 253 (AUG) 3 : 0

Mechanical Behaviour of Materials

Theory of Elasticity. Theory of Plasticity. Review of elementary dislocationtheory. Deformation of single and polycrystals. Temperature and Strain rate effects in plastic flow. Strain hardening, grain size strengthening, solid solution strengthening, precipitation strengthening, dispersion strengthening.martensitic strengthening. Creep, fatigue and fracture.

Ankur Chauhan

Pre-requistes : None

References : Thomas H. Courtney, Mechanical Behaviour of Materials, Waveland Press. ~George E. Dieter, Mechanical Metallurgy, McGraw-Hill Book Company.

MT 261 (AUG) 3 : 0

Organic Electronics

Fundamentals of polymers. Device and materials physics. Polymer electronicsmaterials, processing, and applications. Chemistry of device fabrication,materials characterization. Electroactive polymers. Device physics: Crystal structure, Energy band diagram, Charge carriers, Heterojunctions, Diode characteristics. Device fabrication techniques: Solution, Evaporation,electrospinning. Devices: Organic photovoltaic device, Organic light emitting device, Polymer based sensors.Stability of organic devices.

Praveen Ramamurthy

Pre-requistes : None

References : T. A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers: Theory, Synthesis, Properties and Characterization, CRC Press.~T.A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers:Processing and Applications Edited by Terje A. Skotheim and John R. Reynolds,CRC

MT 271 (AUG) 3 : 0

Introduction to Biomaterials Science and Engineering

This course will introduce basic concepts of biomaterials research and development including discussion on different types of materials used for biomedical applications and their relevant properties. Content: Surface engineering for biocompatibility; Protein adsorption to materials surfaces;Blood compatibility of materials; Immune response to materials; Corrosion and wear of implanted medical devices; Scaffolds for tissue engineering and regenerative medicine; Concepts in drug delivery;

Kaushik Chatterjee

Pre-requistes : None

References : Ratner et al: Biomaterials science: An introduction to materials in medicine,Lecture notes,Literature

MT 245 (AUG) 3 : 0

Transport Processes in Process Metallurgy

Basic and advanced idea of fluid flow, heat and mass transfer. Integral mass, momentum and energy balances. The equations of continuity and motion and its solutions. Concepts of laminar and turbulent flows. Concept of packed and fluidized bed. Non-wetting flow, Natural and forced convection. Unit processes in process metallurgy. Application of the above principles in process metallurgy.

Govind S Gupta

Pre-requistes : None

References : J. Szekely and N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley, New York, 1971~G.H. Geiger and D R Poirier: Transport Phenomena in Metallurgy, Addison-Wesley, 1980.~D.R. Gaskell: Introduction to Transport Phenomena in Materials Processing, 1991.~R.B. Bird, W.E. Stewart and E.N. Lightfoot: Transport Phenomena, John Wiley International Edition, 1960~F.M. White: Fluid

MT 240 (AUG) 3 : 0

Principles of Electrochemistry and Corrosion

Introduction to electrochemical systems, including batteries, fuel cells and capacitors. Designing electrochemical systems with emphasis on thermodynamics, kinetic, and mass transport limitations. Measuring electrochemical properties with various measurement techniques. Basic electrochemical principles governing corrosion. Types and mechanisms of corrosion. Advances in corrosion engineering and control.

Naga Phani B Aetukuri , Sai Gautam Gopalakrishnan

Pre-requistes : Basic knowledge in materials thermodynamics

References : 1. A.J. Bard and L.R. Faulkner, Electrochemical Methods: Fundamentals and Application, 2nd Edition, Wiley India 2006. ISBN:812650
2. M.G. Fontana, Corrosion Engineering, 3rd Edition, McGraw-Hill, N.Y., 1978.

MT 211 (AUG) 3 : 0

Magnetism, Magnetic Materials, and Devices

Fundamentals: Classical and quantum mechanical pictures of magnetism; spin orbit coupling, crystal field environments, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, dipolar and exchange interactions, magnetic domains, magnetic anisotropy, magnetostriction, superparamagnetism, biomagnetism, and spin glass Bulk magnetic Materials: Transition and rare earth metals and alloys. Oxide based magnetic materials. Hard, soft and magnetostrictive materials, Magnetic shape memory alloys, Structure-microstructure-magnetic property correlations. Low dimensional Magnetic systems and devices: Magnetic nanostructures, thin films, and epitaxial heterostructures; exchange bias and exchange coupling, and magneto-optical materials and devices, AMR, GMR, TMR, spin-transfer torque, spin-orbit torque and spin-Hall effect; Multiferroics, magnetoelectric and magnetoionics; nonvolatile magnetic memory, synaptic and neuromorphic computing devices; Experimental techniques: VSM, SQUID, Mossbauer, MFM, Magneto-transport, Magnetooptical Kerr-effect, XMLD and XMCD

Bhagwati Prasad

Pre-requistes : None

References : S. O. Kasap, Principles of Electronic Materials and Devices; Stephen Blundell, Magnetism in Condensed Matter; J.M.D. Coey, Magnetism and Magnetic Materials; B. D. Cullity and C.D. Graham, Introduction to Magnetic Materials; K. M. Krishnan, Fundamental and Application of Magnetic Material

MT 217 (AUG) 3 : 0

Computational Mathematics for Materials Engineers

Vector and tensor algebra; Basics of linear algebra and matrix inversion methods; Coordinate transformations methods; Optimization methods, Probability and statistics; Numerical methods: Concepts of discretization in space/time, implicit, explicit; Solution to ODEs(Euler, Heun, Runge-Kutta methods), PDEs (Elliptic, Parabolic, Hyperbolic), solutions to Laplace equation and applications, transient diffusion and wave equation; Discretization methods (FDM, FVM, FEM); iterative solution schemes Jacobi, Gauss-Seidel, ADI, Multigrid, Fourier-spectral schemes; Root finding methods, interpolation, curve-fitting, regression; Special functions: Bessel, Legendre, Fourier, Laguerre, etc; Computational tools for the solution to all the above problems will be discussed along with canonical examples from materials problems. Software tools, based on python and/or MATLAB, will also be introduced in the course. Instructor: A N Choudhury and S. Gautam G

Abhik N Choudhury , Pikee Priya

Pre-requistes : None

References : Books: Advanced Engineering Mathematics; Erwin Kreyzig Mathematical physics (V. Balakrishnan) Numerical methods for Engineers(Steven C. Chapra and Paymond P. Canale) Numerical Recipes in C(William H. Press, Vetterling, Teutolsky, Flannery)

MT 204 (AUG) 3 : 0

Structure and Properties of Materials

Bonding and crystal structures Bonding in solids, Cohesive energy for ionic and van der Waals solids, simple crystal structures of compounds, metals and alloys. Geometrical crystallography Crystal symmetry and Bravais Lattices, Stereographic projection, Point groups, Space groups, Description of crystal structures with space group. Tensor properties of crystals, Neumann’s principle and related concepts. Heckmann diagram and multifunctionality, Thermodynamics of equilibrium properties of crystals. Point Defects Types of point defects, Equilibrium point defect concentration, Defect chemistry, Effects on diffusion, ionic conductivity, electronic and optical properties Line Defects Continuum and atomistic models, stress fields and energy of dislocations, forces on dislocations, dislocation motion and slip, dislocations in FCC, BCC and HCP metals, Effects on mechanical properties and phase transformations Planar Defects Types of interfaces: heterophase interfaces (S-V, S-L, S S) and homophase interfaces (grain boundaries and stacking faults), Interface thermodynamics and Gibbs-Thompson effect, Anisotropy of interface energy, Effect of interfaces on properties including mechanical behavior, phase transformations, magnetic, optical, etc.

Karthikeyan Subramanian , Rajeev Ranjan

Pre-requistes : This is a foundational course which aims to introduce basics of crystallography, defects and properties. It is meant for Masters, UG (4th Sem) and PhD students.

References : • Structure of Materials, M. D. Graef and M. E. Henry, Cambridge 2007 • Fundamentals of Ceramics, M. W. Barsoum, IOP publishsing Ltd. 2003 • Physical Properties of Crystals, J. F. Nye, Oxford University Press, 2006 • Richard J D Tilley, Defects in Solids, Wiley 2008 • P.G.Shewmon: Diffusion in Solids, 2nd ed., TMS, 1989 • D. Hull and D. J.Bacon: Introduction to dislocations, 4th ed.,

MT 273 (AUG) 3 : 0

Semiconductor Films: Deposition and Spectroscopic Characterization

MT 273 (AUG) 3:0 Semiconductor Films: Deposition and Spectroscopic Characterization This course focuses on the imparting fundamental understanding of the working principles of advanced high vacuum deposition techniques used for the fabrication of semiconductor thin films and devices. The necessary theoretical background, important mechanisms associated with growth of films, and the working principles of various optical spectroscopic techniques will be covered. Semiconductor fundamentals: Common semiconducting materials and their crystal structures; Intrinsic and extrinsic point defects in semiconductors; Electronic band structure; Defect states and their influence on semiconducting properties. Thin film growth processes: Nucleation and growth mechanisms; uncorrelated or random deposition; surface diffusion-controlled growth; ballistic deposition; shadowing effects, etc. Thin film deposition techniques: Hot-wire chemical vapor deposition (HW CVD); plasma-enhanced chemical vapor deposition (PE-CVD); atomic layer deposition (ALD); pulse laser deposition (PLD); RF sputtering, physical vapor deposition (PVD); DC sputtering; Molecular Beam Epitaxy (MBE); thermal evaporation; etc. Spectroscopic characterization of semiconductors: Ultraviolet-visible- near infrared spectroscopy (UV-Vis-NIR); photoluminescence spectroscopy (PL); time-resolved photoluminescence spectroscopy (TRPL); transient spectroscopy (TAS); etc. Hands-on laboratory sessions: Hands-on laboratory sessions and practical demonstrations will be conducted for a few high vacuum deposition techniques and spectroscopic measurements for a few semiconductors' thin films

Sachin R Rondiya

Pre-requistes : None

References : References 1. Thin Film Deposition: Principles and Practice by Donald L. Smith 2. Spectroscopic Methods in Organic Chemistry by Dudley H. Williams and Ian Fleming 3. Principles of Instrumental Analysis by Douglas A. Skoog, F. James Holler, and Stanley R. Crouch 4. Introduction to Spectroscopy by Donald L. Pavia, Gary M. Lampman, George S. Kriz, and James R. Vyvyan 5. Handbook of

MT 310 (AUG) 3 : 0

Manufacturing Process modelling

Introduction to numerical methods (working principle, merits-demerits and applications): FDM, FVM, BEM, FEM, Die filling analysis (nature of flow, back pressure, porosity, air entrapment), Solidification (behavior and filling time), Transport phenomena during solidification: governing equations, phase change, Finite Volume based multiphase and multiscale model of solidification, Initial and boundary conditions, Phase field model of solidification microstructure formation and defect generation, Analytical method and Boundary Element Method to solve the heat conduction equation applied to welding processes, Finite Volume/ Finite Element based multiphase flow model of melt pool transport phenomena and solidification in fusion welding process, Thermo mechanical modeling of the residual stress in welding, Transport phenomena involved in Metal/Ceramic Injection Moulding processes: estimation of filling and cooling time, injection pressure, defect visualization etc., Finite element based continuum model of sintering densification and mechanical behaviour, Molecular dynamics based model of neck growth, microstructure evolution, Finite volume method for modeling additive manufacturing: - melting/ solidification and mass-transfer, Microstructure modelling of multi-layer and multi-track additive manufacturing processes, Forming limit diagrams, FE analysis of deformation behaviour of metals, Finite Element Analysis (FEA) for Metal Forming Processes (forging, rolling, drawing and shearing) and its comparison with the analytical techniques, Analytical and FE modelling of orthogonal machining, FE modelling of chip formation and prediction of cutting forces/machinability of Light alloys and composites

Prosenjit Das

Pre-requistes : Introduction to Manufacturing Science MT 309

References : 1. Computational Fluid Dynamics: The Basics with Applications by J.D.Anderson
2. Goldak, J. A., Akhlaghi, M. (2005). Computational welding mechanics. Germany: Springer.
3. Fundamentals of Powder Metallurgy by W.D. Jones

MT 312 (AUG) 3 : 0

Polymer Engineering and Sustainable Materials

Polymer Science and Engineering Fundamentals
Introduction to polymers, polymer blends and composites, nanostructured materials and nanocomposites. Polymer-polymer miscibility, factors governing miscibility, immiscible systems and phase separation. Importance of interface on the property development, compatibilizers and compatibilization. Blends of amorphous & semi-crystalline polymers, rubber toughened polymers, particulate, fiber reinforced composites.
Nanocomposites and Interface Engineering
Nanostructured materials like nano clay, carbon nanotubes, graphene etc. and polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/ nanocomposites.
Processing and Properties
Various processing techniques like solution mixing, melt processing. Unique properties of blends, composites/nanocomposites in rheological, mechanical, and physical properties and applications.
Sustainable Polymers: Recycling, Circular Economy, and Advanced Materials
polymer lifecycle, its environmental impact, and the shift from a linear to a circular economy, emphasizing principles like reduce, reuse, and recycle. We'll explore mechanical and chemical recycling technologies, including advanced methods like depolymerization and pyrolysis, alongside strategies for design for recyclability. A significant segment focuses on vitrimers, examining their unique chemistry, synthesis, processing, and role in creating self-healing and highly recyclable materials. bioplastics and compostable plastics.

Suryasarathi Bose

Pre-requisites : None

References : 1. "Principles of Polymerization" by George Odian
2. "Introduction to Polymer Science and Technology" by R.J. Young and P.A. Lovell
3. "Polymer Blends and Composites" by L.A. Utracki

Mechanical Engineering

Preface

ME 201 (AUG) 3 : 0

Fluid Mechanics

Fluid as a continuum, mechanics of viscosity, momentum and energy theorems and their applications, compressible flows, kinematics, vorticity, Kelvin's and Helmholtz's theorems, Euler's equation and integration, potential flows, Kutta-Joukowsky theorem, Navier-Stokes equations, boundary layer concept,introduction to turbulence, pipe flows.

Ratnesh K Shukla , Gaurav Tomar , Balachandra Suri

Pre-requistes : None

References : None

ME 242 (AUG) 3 : 0

Solid Mechanics

Analysis of stress, analysis of strain, stress-strain relations, two-dimensional elasticity problems, airy stress functions in recta ngular and polar coordinates, axisymmetric problems, energy methods, St. Venanttorsion, elastic wave propagation, elastic instability and thermal stresses.

Chandrashekhar S Jog

Pre-requistes : None

References : None

ME 243 (AUG) 3 : 0

Continuum Mechanics

Analysis of stress, analysis of strain, stress-strain relations, two-dimensional elasticity problems, airy stress functions in rectangular and polar coordinates, axisymmetric problems, energy methods, St. Venant torsion,elastic wave propagation, elastic instability and thermal stresses.
Introduction to vectors and tensors, finite strain and deformation- Eulerian and Lagrangian formulations, relative deformation gradient, rate of deformation and spin tensors, compatibility conditions, Cauchy's stress principle, stress tensor,conservation laws for mass, linear and angular momentum, and energy. Entropy and the second law, constitutive laws for solids and fluids, principle of material frame indifference, discussion of isotropy,linearized elasticity, fluid mechanics.

Chandrashekhar S Jog

Pre-requistes : None

References : Malvern,L.E.,Introduction to the Mechanics of a continuous medium ,Prentice Hall,1969. Gurtin

ME 246 (AUG) 3 : 0

Introduction to Robotics

Robot manipulators: representation of translation, rotation, links and joints,direct and inverse kinematics and workspace of serial and parallelmanipulators, dynamic equations of motion, position and force control and simulation.

Jishnu Keshavan

Pre-requistes : None

References : Ghosal, A., Robotics: Fundamental Concepts and Analysis,,Oxford University Press, 2006,Notes and recent research papers.

ME 250 (AUG) 3 : 0

Structural Acoustics

Vibration and acoustic response of an infinite plate in contact with an acoustic half space to a line force (Crighton’s solution). Complex variables,integration with branch cuts. Fluid-structure coupling in 2-D flexible-walled waveguides using asymptotic expansions (rectangular and cylindrical geometries). Coupling of sound with flexible enclosures. Sound radiation from finite rectangular plates and cylindrical shells. Transform and Rayleigh integral methods. Coincidence and wave number spectra, wave impedance, radiation efficiency.

Venkata R Sonti

Pre-requistes : None

References : None

ME 255 (AUG) 3 : 0

Principles of Tribology

Surfaces, theories of friction and wear, friction and wear considerations in design, viscosity, hydrodynamic lubrication, Reynolds equation, coupling of elastic and thermal equations with Reynolds equation. Elasto-hydrodynamic lubrication. Mechanics of rolling motion, hydrostatic lubrication, lubricants, tribometry, selection of tribological solutions.

Bobji M S

Pre-requistes : None

References : None

ME 261 (AUG) 3 : 0

Engineering Mathematics

Vector and tensor algebra: Sets, groups, rings and fields, vector spaces, basis, inner products, linear transformations, spectral decomposition, tensor algebra, similarity transformations, singular value decomposition, QR and LU decomposition of matrices, vector and tensor calculus, system of linear equations (Krylov solvers, Gauss- Seidel), curvilinear coordinate transformations. Ordinary and partial differential equations: Characterization of ODEs and PDEs, methods of solution, general solutions of linear ODEs,special ODEs, Euler-Cauchy, Bessel's and Legendre's equations, Sturm-Liouville theory, critical points and their stability. Complex analysis: Analytic functions, Cauchy-Riemann conditions and conformal mapping. Special series and transforms: Laplace and Fourier transforms, Fourier series, FFT algorithms,wavelet transforms.

Venkata R Sonti , Shubhadeep Mandal , Akshay Joshi

Pre-requistes : None

References : None

ME 283 (AUG) 3 : 0

Two Phase Flows and Boiling Heat Transfer

Characterization of two phase flow patterns (bubbly, slug, annular, mist, stratified, etc), homogeneous and heterogeneous flow models, suspension of particles in fluids, particulate fluidization, Bubble dynamics, Rayleigh-Plesset Equation, Boiling and Condensation Heat Transfer, Homogeneous and heterogeneous nucleation, Hydrodynamic stability of stratified fluids, molecular theory of surface tension, contact line dynamics, dewetting pathways.

Susmita Dash

Pre-requistes : None

References : None

ME 285 (AUG) 3 : 0

Turbomachine Theory

Introduction to turbo-machines, mixing losses, review of vorticity, profile changes in contracting and expanding ducts. Brief review of diffusers, rotating co-ordinate system, total enthalpy, rothalpy,Euler turbine equation, velocity triangles. Specific speed and Cordier diagram, cascade aerodynamics. Elemental compressor stage, reaction work and flow coefficients. Equations of motion in axisymmetric flow, simple and extended radial equilibrium. Elemental axial turbine stage, radial and mixed flow machines, work done by Coriolis forces and by aerofoil action, the centrifugal compressor, vaned and vaneless diffusers.

Raghuraman N Govardhan

Pre-requistes : None

References : Sabersky,R.H.,and Acosta,A.,Fluid Flow: A First Course in Fluid Mechanics

ME 297 (AUG) 1 : 0

Departmental Seminar

The student is expected to attend and actively take part in ME departmental seminars for one semester during his/her stay.

Akshay Joshi

Pre-requistes : None

References : None

ME 259 (AUG) 3 : 0

Nonlinear Finite Element Methods

Introduction to structural nonlinearities, Newton-Raphson procedure to solve nonlinear equilibrium equations, finite element procedures for 1-D plasticity and visco-plasticity. Return mapping algorithm. Continuum plasticity theory. Stress updated procedures. Treatment of nearly-incompressible deformation.Fundamentals of finite deformation mechanics-kinematics, stress measures,balance laws, objectivity principle, virtual work principle. Finite element procedure for nonlinear elasticity. Lagrangian and spatial formulations.Finite element modeling of contact problems. Finite element programming.

Narasimhan R

Pre-requistes : None

References :
Bathe, K.J., Finite Element Procedures, Prentice Hall of India, New Delhi 1997. ~Zienkiewicz, O.C., and Taylor, R.L., The Finite Element

ME 260 (AUG) 3 : 0

Structural Optimiztion:Size, Shape, and Topology

A quick overview of finite-variable optimization and calculus of variations. Analytical size optimization of bars and beams for stif fness, flexibility,strength, and stability criteria in the framework of variational calculus.Gradient-based computational optimization of trusses, frames, and continuum structures. Sensitivity analysis for parameter, shape, and topology variables. Shape optimization. Topology optimization. Design parameterization for topology optimization of coupled structural problems involving thermal, electro-thermal, electrostatic, fluid, and other multiphysics domains.

Ananthasuresh G K

Pre-requistes : None

References : NPTEL MOOC:https://nptel.ac.in/courses/112/108/112108201/~Haftka, R.T. and Gurdal, Z., "Elements of Structural Optimization," Kluwer Academic Publishers,1992.~Bendsoe, M. P. and Sigmund, O., "Topology Optimization: Theory, Methods, and Applications," Springer, 2003.~Haug, E. J., Choi, K.K., and Komkov, V.,“Design Sensitivity Analysis of Structural Systems, ”Academic

ME 262 (AUG) 3 : 0

Wave Propagation in Solids

Uniaxial stress waves (equation of motion, x-t diagrams, reflection at boundaries, impedance mismatch); Uniaxial strain waves (method of characteristics); Bulk waves in 2D and 3D media (longitudinal & shear waves, Rayleigh and Stoneley waves, plane waves in 2D, reflection and refraction); Wave guides (dispersion, phase & group velocities, vibrating beams, Love waves, plate problems, 3D bar problems); Spherical waves (Impact of half spaces, Boussinesq & Lamb problems, unloading waves); Shock waves (1D shock waves, Rankine-Hugoniot relations, equation of state); Dynamic testing techniques (Split Hopkinson bars, plate impact, Taylor test, expanding ring).

Debashish Das , Akshay Joshi

Pre-requistes :

References : •M.A. Meyers, “Dynamic behavior of Materials”, Wiley, New York, NY, 1994. •J. D. Achenbach, “Wave propagation in elastic solids”, North-Holland, 1990. •H. Kolsky, “Stress waves in solids”, Dover, New York, 1963. •Zukas et al., “Impact dynamics”, Krieger, Malabar, FL, 1992. •L.M. Brekhovskikh & V. Goncharov, “Elastic Waves in Solids”, Springer, Berlin, 1994. •J. Miklowitz, “The Theory of

ME 306 (AUG) 3 : 0

Analytical and Statistical Thermodynamics

This course will cover mathematical aspects of macroscale and microscopic thermodynamics. The prerequisites for this course are courses in engineering mathematics and basic thermodynamics. The course will be covered in four parts: 1.Classical theory of thermodynamics: Geometry of fundamental relations, Caratheodory’s theorem, thermodynamic potentials; 2.Thermodynamic stability: Phase equilibria and separation, thermodynamics of surfaces and multi-component systems 3.Statistical equilibrium thermodynamics: Microcanonical and canonical ensembles, Ising model solution, correlation functions and phase change 4.Non-equilibrium thermodynamics: Langevin equation, fluctuation-dissipation theorem, Fokker-Planck equation, Diffusion equation and dynamic mobility

Gaurav Tomar , Koushik Viswanathan

Pre-requistes :
The prerequisites for this course are courses in engineering mathematics and basic thermodynamics.

References : 1.H Callen, Thermodynamics and an introduction to thermostatistics 2.S Safran, Statistical Thermodynamics of Surfaces, Interfaces and Membranes 3.F Reif, Statistical Physics (Berekely Physics Series Vol.5) 4.K Huang, Statistical Mechanics 5.V Balakrishnan, Elements of Nonequilibrium Statistical Mechanics

ME 263 (AUG) 2 : 1

Applied Finite Element Analysis

Python Primer, syntax, formulas, loops and lists. Functions and branching structures. Importing python packages, using dumpy and matplotlib.

Overview and introduction to FEniCS, installation procedures, accessing documentation and web resources.

Discussion of the scalar Poisson problem, recap of strong and weak formulations, Galerkin approximation of the weak form, derivation of matrix-vector equations. Implementation of the problem in FEniCS, generating meshes, specifying boundary conditions, choosing finite element function spaces, defining linear and bilinear forms, concepts of form compilation, specifying PETSc solvers, post-processing and visualization

Discussion of the vectorial linear elasticity problem, recap of equilibrium equations, weak formulation, displacement boundary conditions. Implementation of the problem in FEniCS, defining vector-valued solution and test functions, tensor-valued computations, computing eigenvalues and eigenmodes.

Discussion of the Stokes equations for fluid flow, pressure-velocity formulation, velocity boundary conditions, mixed variational formulation, discussion of the inf-sup condition. Implementation of the problem in FEniCS, defining mixed function spaces, verification of computations with exact solutions, the Taylor-Hood P2/P1, stabilization techniques and the mini-element.

Discussion of the nonlinear Poisson equation, heat conduction with temperature-dependent conductivity, variational formulation, finite element discretization and consistent linearization. Implementation of the problem in FEniCS, Newton iterations for solutions.

Discussion of the nonlinear hyperelasticity problem, equilibrium equations with hyperelastic materials (stress,strains,constitutive relationships), variational formulation, deriving residuals and their linearization. Implementation of the problem in FEniCS, specifying nonlinear solver parameters, specifying initial guesses for solutions.

Discussion of time-dependent PDEs, parabolic equations for transient heat conduction, deriving the semi-discrete equations. Implementation of the problem in FEniCS, time-stepping loop using implicit-Euler, trapezoidal rule, specifying time-dependent expressions.

Discussion of the dynamic hyperelasticity problem, variational formulation and its semi-discretization. Implementation of the problem in FEniCS, explicit and implicit integration methods, comparison with linearized responses.

Discussion of error control in finite element simulations, computing convergence rates of numerical solutions, aposteriori error estimators/error indicators, mesh adaptation algorithms, Implementation of h-adaptivity in FEniCS.

Ramsharan Rangarajan

Pre-requistes :
A course on linear finite element methods, preferably ME 257.

References :

[1] https://fenicsproject.org

[2] https://jsdokken.com/dolfinx-tutorial/

ME 299A (AUG) 0 : 9

MTech Project A

This is the first part (of two) of the MTech (coursework) project. As part of this project course, students will learn to independently analyze a scientific problem by performing comprehensive literature survey, preliminary data acquisition and analysis.

Aloke Kumar

Pre-requistes : None

References : Upon discussion with advisor

Dept. of Design and Manufacturing

Preface

MN 202 (AUG) 3 : 0

Digital Manufacturing

Product modelling, Process Modelling, Intelligent machines, Autonomous devices in manufacturing, Interoperability of digital models in manufacturing,computer aided inspection and verification, Digital Thread and applications of digital models in maintenance and operations

Dibakar Sen

Pre-requisites : None

References : None

MN 205 (AUG) 1 : 2

Makers’ Project

Each maker's project will be offered to be carried out in groups of 4-5 students. The course will involve two components: a common primer on metrology of mechanical, electrical, optical, contact and non-contact measurements (about 4 weeks, to be taught by appropriate faculty from the programme),followed by carrying out a single project by each group (8 weeks). The project will be allotted from a list of 'assemble- program-characterize' projects to be shared with students each year.

Vishal Singh

Pre-requisites : None

References : None

PD 201 (AUG) 2 : 1

Elements of Design

Visual language, visual elements, visual perception, visual deception. Universal principles of design. Theory of colour, studies in form, graphic compositions, grid structure, spatial analysis and organization. Visual expressions in nature.

Vishal Singh

Pre-requisites : None

References : Young, F.M., Visual Studies, Prentice-Hall, USA.,Lidwell, W.,Holden, K., and Butler, J., Universal Principles of Design,Rockport,USA.,Evans, P., and Thomas, M., Exploring the Elements of Design,Thomson, USA.

PD 202 (AUG) 2 : 1

Elements of Solid and Fluid Mechanics

Analysis of stress and strain, failure criteria, dynamics and vibrations. Control of engineering systems, elements of fluid mechanics drag and losses, thermal analysis, problems in structural and thermal design.

Manish Arora

Pre-requistes : None

References : Shigley, J.E., Mechanical Engineering Design, McGraw Hill.,White, F.M., Fluid Mechanics, Tata McGraw Hill.,Gupta, V., Elements and Heat and Mass Transfer, Sage Publishers.

PD 207 (AUG) 1 : 2

Product Visualization, Communication and Presentation

Object drawing fundamentals, theory of perspectives, exploded views, sectional views. Fundamentals of lighting, idea representation and communication methods and pitfalls. Materials, tools and techniques of representation in various media like pencil, ink, colour etc. Rendering techniques, air brush illustration. Idea documentation. Fundamentals of photography, video-graphy and digital media. Dark room techniques. Studio assignments in all the above topics. Mock-up modeling and simulation in various materials.

Vishal Singh

Pre-requistes : None

References : Geometry of design: Studies in proportion and composition, ISBN: 1568982496,Foundation of Art & Design 1856693759,Earle,J.E.,Engineering Design Graphics, Addison Wesley, ISBN 020111318x

PD 209 (AUG) 2 : 1

New Product Development: Concepts and Tools

Technology-based products, business context, front-end of innovation, opportunity identification, target markets, integrated teams, product features, differentiation from competition, business cases, product architecture,designing and prototyping products, planning for manufacturing capabilities,marketing and sales programs

Vishal Singh

Pre-requistes : None

References : (1) Ulrich, K.T., and Eppinger, S.D., Product Design and Development, 2nd edition, (2) Philip Kotler, Kevin Lane Keller,Marketing Management, 15th edition, (3) Douglas Smith and Jon Katzenbach, The Wisdom of Teams: Creating the High-Performance Organization, 2015 edition.

PD 233 (AUG) 2 : 1

Design of Biomedical Devices and Systems

Medical Device Classification, Bioethics and Privacy, Biocompatibility and Sterilization Techniques,Design of Clinical Trials, Design Control & Regulatory Requirements, Introduction to specific medical technologies: Biopotentials measurement (EMG, EOG, ECG, EEG), Medical Diagnostics (In vitro diagnostics), Medical diagnostics (Imaging), Minimally Invasive Devices,Surgical Tools and Implants, Medical Records and Telemedicine. The course will include guest lectures by healthcare professionals giving exposure to ummet needs in the healthcare technologies and systems.

Manish Arora

Pre-requistes : None

References : Paul H king, Richard C. Fries, Arthur T. johnson, Design of Biomedical Devices and Systems. Third edition, ISBN 9781466569133,Peter J.Ogrodnik, Medical Device Design:Innovation from Concept to Market, Academic Press Inc; ! edition (2012), ISBN-10:0123919428,Stefanos Zenios, Josh Makower, Paul Yock, Todd J.Brinton, uday N. Kumar, Lyn Denend, Thomas

PD 234 (AUG) 2 : 1

Intelligent User Interface

Basics of Artificial Intelligence(heuristic and state space search,Bayes Ru

Pradipta Biswas

Pre-requistes : None

References : Shneiderman B. "Designing The User Interface - Strategies for Effective Human-Computer Interaction.",Buxton B., Sketching User Experiences: Getting the Design Right and the Right Design, Morgan Kaufmann,Norman K (Ed), Wiley Handbook of Human Computer Interaction, Wiley 2017

PD 239 (AUG) 0 : 3

Design and Society

Independent study/research on a chosen topic by students under the supervisionof faculty members. Presentation of seminar on work done. The course also includes invited seminars on various aspects of product design and marketing issues. The focus is on real life situations from practicing professionals.

Vishal Singh

Pre-requistes : None

References : None

PD 204 (AUG) 2 : 1

Basics of Electronics for Product Design and Manufacturing

Introduction to sensors and actuators, Static vs. current electricity, Passive and active components of electrical systems, Type of electrical sources, Introduction to linear and non-linear electrical components, Basic circuit theory and analysis of DC circuits, Basics of AC circuit, Basics of power distribution, domestic and industrial electrical wiring and safety, AC-AC and AD-DC conversion, Voltage regulator, Constant current source, Sensor biasing (voltage vs. current biasing) and transduction, Transistors: Type and application as amplifier and switch, Basic op-amp circuit, Introduction to digital logic, Combinational and sequential circuit, Discrete signals: Number systems and binary arithmetic, Logic gates, Flip-Flops, Sampling theory, Sampling and hold circuit, anti-aliasing filter, Digital to Analog (DAC) and Analog to Digital (ADC)Conversions, Different types of ADC and DAC with their benefits and limitations, Basics of Microprocessors and microcontrollers. Introduction to sens

Abhijit Biswas

Pre-requistes :

Students without electrical or electronics or instrumentation

References : •Roy Choudhury, D. (1988). Networks and Systems. India: Wiley Eastern. •Jain, B., Jain, S., Roy Choudhury, D.(2010).Linear Integrated Circuits. United Kingdom: New Age Science Limited. •M.Morris Mano and Michael D. Ciletti, Digital Design, Pearson, Prentice Hall, https://archive.org/details/morrismano4thedition/page/n 1/mode/2up •Dam, B. v. (2009). Microcontroller Systems Engineering:45

PD 206 (AUG) 2 : 1

Basics of Computing, AI and Data Science for Design and Manufacturing

Introduction to sensors and actuators, Static vs. current electricity, Passive and active components of electrical systems, Type of electrical sources, Introduction to linear and non-linear electrical components, Basic circuit theory and analysis of DC circuits, Basics of AC circuit, Basics of power distribution, domestic and industrial electrical wiring and safety, AC-AC and AD-DC conversion, Voltage regulator, Constant current source, Sensor biasing(voltage vs. current biasing) and transduction, Transistors: Type and application as amplifier and switch, Basic op-amp circuit, Introduction to digital logic, Combinational and sequential circuit, Discrete signals:Number systems and binary arithmetic, Logic gates, Flip-Flops, Sampling theory, Sampling and hold circuit, anti-aliasing filter, Digital to Analog (DAC) and Analog to Digital (ADC)Conversions, Different types of ADC and DAC with their benefits and limitations, Basics of Microprocessors and microcontrollers.

Abhijit Biswas

Pre-requistes :

Students without computer science or data science or

References : •Roy Choudhury, D. (1988). Networks and Systems. India: Wiley Eastern. •Jain, B., Jain, S., Roy Choudhury, D.(2010).Linear Integrated Circuits. United Kingdom: New Age Science Limited. •M.Morris Mano and Michael D. Ciletti, Digital Design, Pearson, Prentice Hall, https://archive.org/details/morrismano4thedition/page/n 1/mode/2up •Dam, B. v. (2009). Microcontroller Systems Engineering:45

MN 207 (AUG) 2 : 1

Intelligent Mobile Robots: Perception, Action and Control

Introduction to Mobile Robotics Locomotion Principles Kinematic Modelling Perception Control System Design Localization Motion Planning Multi-robot systems ROS and Matlab for Robotics Autonomy in Mobile Robot

Abhra Roy Chowdhury

Pre-requistes :

References : • H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion: Theory, Algorithms and Implementations, PHI Ltd., 2005. • R. Siegwart, I. R. Nourbakhsh, Introduction to Autonomous Mobile Robots, MIT Press,2011 • G. Dudek and M. Jenkin, Computational Principles of Mobile Robotics, Cambridge University Press, 2010 • H. Asama, T.

MN 299 (AUG) 0 : 24

Dissertation Project

Each project will be offered to be carried out in groups of 2-3 students. The project will involve an indepth development or in-depth study in an area in smart manufacturing

Vishal Singh

Pre-requistes : None

References : -

PD 298 (AUG) 0 : 22

Dissertation Project

Spread over 15 months, commencing immediately after the second semester. It involves complete design, prototype fabrication, demonstration of requirement satisfaction along with full documentation.

Vishal Singh

Pre-requistes : None

References : Gerhard Pahl , Wolfgang Beitz , Jörg Feldhusen , Karl-Heinrich Grote, Engineering Design A Systematic Approach, Springer, ISBN:978-1-84628-318-5

Mobility Engineering

Preface

IISc's Knowledge and E-Learning Network

Preface

IISc's Knowledge and E-Learning Network

Artificial Intelligence Stream

Preface

E1 277o (AUG) 3 : 1

Reinforcement Learning

Introduction to Reinforcement Learning, Multi-armed bandits, Markov decision processes, Dynamic Programming - Value and Policy Iteration Methods, Model-Free Learning Approaches, Monte-Carlo Methods, Temporal Difference Learning, Q-learning, SARSA, Double Q-learning, Value Function Approximation Methods - TD Learning with Linear Function Approximation, Neural Network Architectures, Deep Q-Network Algorithm, Policy Gradient Methods, Actor-Critic Algorithms.

Shalabh Bhatnagar

Pre-requistes :

References : 1. R. Sutton and A. Barto, Reinforcement Learning, MIT Press, 2'nd Ed., 2018 2. D.Bertsekas, Reinforcement Learning and Optimal Control, Athena Scientific, 2019 3. Selected Recent Papers

DS 265o (AUG) 3 : 1

Deep Learning for Visual Analytics

Basics of machine learning and computer vision, CNN basics, Loss function and back propagation, Object Recognition, Detection and Segmentation. Recurrent Neural Networks, LSTM, Generative Adversarial Networks (GANs), Self-supervised learning, Transformers, Explainable AI, Adversarial Robustness of Deep models.

Venkatesh Babu R

Pre-requistes :

References : 1. Dive into Deep learning, Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola (Online) 2. Recent Research papers.

AI 299o (AUG) 0 : 27

MTech Dissertation Project

Chandramani Kishore Singh

Pre-requistes : None

References : None

E1 286o (AUG) 3 : 1

Deep Generative Models

Prathosh A P

Pre-requistes : None

References : None

Data Science & Business Analytics Stream

Preface

DA 231o (AUG) 3 : 1

Data Engineering at Scale

Yogesh L Simmhan

Pre-requistes : None

References : None

DA 227o (AUG) 3 : 1

Data Mining

Parthasarathy Ramachandran

Pre-requistes : None

References : None

DA 299o (AUG) 0 : 32

DSBA Stream Project

Deepak Narayanan Subramani

Pre-requistes : None

References : None

DA 245o (AUG) 3 : 1

Linear Optimization and Network Science

Tarun Rambha

Pre-requistes : None

References : None

DA 206o (AUG) 3 : 1

Foundations of AI

Sundeep Prabhakar Chepuri

Pre-requistes : None

References : None

DA 241o (AUG) 3 : 1

Managerial Economics

Sumirtha Gandhi

Pre-requistes : None

References : None

DA 232o (AUG) 3 : 1

Intelligent User Interface

Pradipta Biswas

Pre-requistes : None

References : None

Electronics & Communication Engg. Stream

Preface

E2 202o (AUG) 3 : 1

Random Process

Srikanth Krishnan Iyer

Pre-requistes : None

References : None

E1 220o (AUG) 3 : 1

Linear Algebra

Kunal Narayan Chaudhury

Pre-requistes : None

References : None

E2 299o (AUG) 0 : 28

MTech(Online) ECE Stream Project

Debdeep Sarkar

Pre-requistes : None

References : None

E8 205o (AUG) 3 : 1

Antennas and Circuits for Emerging Communication a

Debdeep Sarkar

Pre-requistes : None

References : None

Division of Physical and Math. Sciences

Preface

The Division of Physical and Mathematical Sciences comprises the Department of Mathematics, Department of Instrumentation and Applied Physics, Department of Physics, Centre for Cryogenic Technology and Centre for High Energy Physics (formerly Theoretical Studies). The Joint Astronomy and Astrophysics Programme also comes under its purview.

The courses offered in the Division have been grouped into six broad areas. These areas have been identified by code letters as follows:

IN Instrumentation and Applied Physics

MA Mathematics

PH Physics

AA Astronomy & Astrophysics

HE High Energy Physics

The course numbers have the prefix of the code letter followed by the numbers. The first digit indicates the level of the course.

There are specific requirements for completing a Research Training Programme for students registering for research conferments at the Institute. For specific individual requirements, the students are advised to approach the Departmental Curriculum Committee.

The Department of Physics and the Centre for High Energy Physics offer an Integrated PhD Programme to which BSc graduates with an adequate background of Physics and Mathematics are admitted.

The Integrated PhD programme in the Mathematical Sciences is offered by the Department of Mathematics to which BSc graduates with an adequate knowledge of Mathematics are admitted.

An M Tech programme in Instrument Technology is offered in the Department of Instrumentation and Applied Physics. For all these programmes, most of the courses are offered by the faculty members of the Division, but in certain special areas, courses offered in other Divisions may also be chosen.

Prof. Kaushal Verma

Dean

Division of Physical & Mathematical Sciences

Cryogenic Technology

Preface

High Energy Physics

Preface

HE 386 (AUG) 3 : 0

Experimental High Energy Physics

Particles and interactions in the standard model. Strong, weak and electromagnetic interactions. Kinematics of particle interactions. Concepts of accelerators, linear and circular Accelerators. Introduction to particle detectors, interaction of particles with matter. Gaseous detectors,scintillator detectors, solid state detector. Readout electronics, vertex detection and tracking. Calorimetry for electrons, photons, charged hadrons and neutrons. Particle identification and detector systems. Experimental tests of the building blocks of matter and their fundamental interactions. Examples of QCD tests, top quark, Z and W bosons, Higgs boson, new particle searches.Review of some particle physics experiments, concepts of collider physics,basic phenomenology of a hard scattering process. Data analysis techniques in collider physics, statistical analysis in particle physics.

Jyothsna Rani Komaragiri

Pre-requistes : None

References : None

HE 398 (AUG) 3 : 0

General Relativity

Review of tensor calculus and properties of the Riemann tensor. Killing vectors, symmetric spaces. Geodesics. Equivalence principle and its applications. Scalars, fermions and gauge fields in curved space-time. Einstein's equations and black hole solutions. Schwarzschild solution, Motion of a particle in the Schwarzschild metric. Kruskal extension and Penrose diagrams. Reissner-Nordstrom solution, Kerr solution. Laws of black hole physics. Gravitational collapse. Oppenheimer-Volkoff and Oppenheimer-Synder solutions, Chandrasekhar limit. Csomological models, Friedmann-Robertson-Walker metric. Open, closed and flat universes. Introduction to quantizing fields in curved spaces and Hawking radiation.

Gaurav Narain

Pre-requistes : None

References : Landau L.D. and Lifshitz E.M.,The Classical Theory of Fields,Pergamon Press,1975~Weinberg S., Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, John Wiley & Sons, 1972~Wald R.M., General Relativity, Overseas Press, 2006~'t Hooft G., Inroduction to General Relativity, Introduction to the theory of Black Holes, http://www.phys.uu.nl/thooft~

HE 395 (AUG) 3 : 0

Quantum Field Theory I

Scalar, spinor and vector fields. Canonical quantisation, propagators. Symmetries and Noether theorem. Path integrals for bosonic and fermionic fields, generating functionals. Feynman diagrams. Klein-Gordon and Dirac equations. Discrete symmetries: P,C,T. S-matrix, LSZ reduction formula. Interacting scalar and Yukawa theories. Scattering cross-sections, optical theorem, decay rates. Loop diagrams, power counting, divergences. Renormalization, fixed point classification. One loop calculations. Callan- Symanzik equations, beta functions. Effective field theory.

Prasad Satish Hegde

Pre-requistes : None

References : Zee A.,Quantum Field Theory in a Nutshell (Second edition),Princeton University Press,2010~Srednicki M., Quantum Field Theory, Cambridge University Press, 2007~Ryder L.H., Quantum Field Theory (Second edition), Cambridge University Press, 1996~Ramond P., Field Theory: A Modern Primer (Second edition), Levant Books, 2007~

HE 314 (AUG) 3 : 0

Astroparticle Physics

Cosmic rays: formation, propagation, spectral features, detection.
Stars: stellar nucleosynthesis; thermonuclear runaway and core-collapse supernovae; degenerate compact stars -- white dwarfs and neutron stars, structure and evolution, pulsar mechanism.
Particle cosmology: Big Bang nucleosynthesis; baryon acoustic oscillations and cosmic microwave background -- spectral distortions and temperature/polarization anisotropies; the cosmological constant problem.
Neutrino astronomy: geo-, atmospheric, solar, (pre-)supernova, AGN, cosmogenic, cosmological neutrino fluxes and detection.
Dark matter: evidence; particle candidates -- axions, WIMPs, composites, sterile neutrinos; cosmological production mechanisms; experimental detection efforts in direct and indirect searches.
Observational anomalies: Galactic Centre GeV excess, antiparticle excesses in cosmic rays, 3.5 keV and 511 keV lines, DAMA/LIBRA anomaly.

Nirmal Raj

Pre-requistes :
PH 217 Fundamentals of Astrophysics,
HE 215 Nuclear and Particle

References :
Astroparticle Physics byClause Grupen.
Fundamentals of Neutrino Physics and Astrophysics by Carlo Giunti and Young Kim.

Instrumentation and Applied Physics

Preface

IN 201 (AUG) 3 : 0

Analytical Instrumentation

Principles, instrumentation, design and application of UV, visible and IR spectroscopy, mass spectrometry, Mossbauer and NMR spectroscopy, X- ray methods of analysis including powder diffraction, wavelength and energy dispersive x-ray fluorescence. Electron microscopy and microprobe. ESCA and AUGer techniques, photo electron spectroscopic methods, scanning tunneling and atomic force microscopy. Chromatography, thermal analysis including DTA, DSC and TGA. Thermal wave spectroscopic techniques such as photo-acoustic, photo-thermal deflection and photopyro-electric methods.

Manukumara Manjappa

Pre-requistes : None

References : Willard,H.W.,Merritt,L.L.,Dean

IN 221 (AUG) 3 : 0

Sensors and Transducers

Electromagnetics, Electromagnetic Sensors, Electrical Machines, Semiconductor fundamentals, MOS capacitor based sensors, FET based sensors, Mechatronics, Microelectromechanical system, Mechanical Transducers, Photonics, Imaging Sensors, Fiber optics, interferometry, Measurements on the Micro and Nanoscale, Fundamental limits on amplifiers, Fabrication of sensors, Photolithography

Manish Arora , Chandni U , Baladitya Suri

Pre-requistes : None

References : W.Bolton, Mechatronics, Longman, 2015~B.E.A.Saleh and M.C.Teich, Fundamentals of Photonics, John Wiley and Sons, 2007~D. Pozar, Microwave Engineering,John Wiley and Sons, 2012~Robert F. Pierret, Gerold W.Neudeck,Modular Series on Solid State Devices, Pearson, 1988~M. J.Madou, Fundamentals of Microfabrication, CRC Press, 2002

IN 227 (AUG) 3 : 0

Control Systems Design

Dynamics of linear systems, Laplace transforms, analysis of feedback controlsystems using Nyquist plots, Bode plots and Root Locus, design of controlsystems in single-degree of-freedom configuration using direct design,proportional-integral-derivative control, lead-lag ompensation, design ofcontrol systems in two-degree of-freedom configuration to achieve robustness,Quantitative feedback theory control of non-minimum phase systems, Bodesensitivity integrals, use of describing functions to analyze and compensatenonlinearities.

Jayanth G R

Pre-requistes : None

References : Horowitz I.M.,Synthesis of Feedback Systems,Academic Press,1963.,Goodwin G. C.

IN 232 (AUG) 3 : 0

Concepts in solid state physics

Vibrations in solids; Electrons in Metals; Phonons; Tight binding chain; Chemical bonding in solids; Crystal structure; Real and Reciprocal Space; Scattering experiments; Waves in reciprocal space; Band structure and optical properties; Fermi surfaces; Introduction to semiconductors; Magnetism; Practical examples and review.

Chandni U , Tapajyoti Das Gupta

Pre-requisites : None

References : H.Ibach and H.Luth, Solid State Physics:An Introduction to Principles of Materials Science, Springer, 4th Edition 2009~Steven H. Simon, The Oxford solid state basics, Oxford University Press, 2013~Aschroft and Mermin, Solid State Physics

IN 203 (AUG) 3 : 0

Micro to Quantum Supercapacitor Devices

Fundamentals of supercapacitor, Supercapacitor Fabrication, State-of-art supercapacitor design, Supercapacitor materials, Macro supercapacitor, Planar micro supercapacitor, Self-powered supercapacitor, Design of planar supercapacitor electrodes, Differences in macro-supercapacitor and planar supercapacitors, Mechanism of electrochemical interactions, Energy density and power density, Fundamentals of electromagnetic interaction in device design, Optically active devices and circuit design, Instrumentation of supercapacitor, Flexible electronics of supercapacitor, Ultra small planar devices, Device design parameters, Quantum Supercapacitors, Current technological advancements and future roadmap, Future Applications

Abha Misra

Pre-requisites :

References : 1- Electrochemical Supercapacitors, Author: B E Conway. 2- Semiconductor Devices and Circuits (Oxford Higher Education), by Aloke Dutta 3- Physics of Optoelectronics, by Michael A. Parker

IN 277 (AUG) 2 : 1

Instrumentation Electronics Laboratory

Applications of operational amplifiers, active filters, oscillators, A/D and D/A converters, phase-locked loops, mixers, lock-in amplifiers, switched mode power supplies, speed control of motors using PWM, introduction to microcontrollers and microprocessors. (There will be lectures and laboratory sessions on each of the topics mentioned here.)

Atanu Kumar Mohanty

Pre-requisites :

References : *Paul Horowitz and Winfield Hill, The Art of Electronics, Cambridge University Press, 2015 *Jacob Millman and Christos C. Halkias, Integrated Electronics, McGraw-Hill International Student Edition,1972 *Robert W. Erickson and Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 2001 *R.S. Kaler, Microprocessors and Microcontrollers, I. K. International Publishing

IN 206 (AUG) 2 : 1

Signals and Systems for Digital Health

Digital Health - Introduction: Need, case studies, basics - mHealth and eHealth, Impact, Informatics: Health Level Seven (HL7), Integrating the Healthcare Enterprise (IHE), Vendor Neutral Archives (VNAs), Open source/ data/innovation – opportunities, Regulatory Affairs in Digital Health (FDA/DCGI), and Ayushman Bharat Digital Mission

Signals and Systems: Signals and Systems Review, LTI Systems, Signal Processing Review: DFT and its properties, Nyquist Sampling Theorem, Low-Pass Filtering, Filters - Chebyschev Filter and Butterworth Filter, Multi-resolution analysis, Filter Banks, Wavelets, Reconstruction of Bandlimited Signals.

Biomedical Signals and Systems: Basics of Physiology (brain, heart and muscle), ECG Signal Acquisition (Electrical activity of heart, chest leads/montage, action potential in pacemaker and other regions; action potential relation to ECG Waveform; Reading ECG); EEG Signal Acquisition (Neural activity in the brain, Action potential, post-synaptic potential, Signal Propagation in the brain, EEG montage, EEG Signal Acquisition); Basics of phonocardiography; EEG and ECG data processing, ECG and EEG signal processing (EEGLab).

Biomedical Wearable Devices: Wearable Sensors for health monitoring: Accelerometers (data acquisition and interpretation), glucose sensing (acquisition methods and comparison), Wearable ECG & EEG based on dry electrodes, pulse-oximeter. Medical regulatory approvals.

Jaya Prakash

Pre-requistes : None

References : 1) S. Haykin and B. V. Veen, “Signals and Systems”, 2nd Edition, Wiley Publisher (2007). 2) K. Najarian, and R. Splinter, “Biomedical Signal and Image Processing,” 2nd Edition, CRC Press (2012). 3) Journal Papers, Case Reports, and Review Articles

IN 280 (AUG) 2 : 1

Optical Instrumentation

Building-Blocks of Optical Instrumentation: Properties of Light and Physical Principles (Refraction, Diffraction, Scattering and Interference), Optical Components (such as Elements, Sources and Detectors) and Modules (such as Optical Fibers and Imaging Systems), Optical Sensors and Transducers. Design & Characterization of Optical Systems: Signals, Systems, Analysis, Measurement, Characterization and Calibration. Point-Spread Function, Optical Transfer Function. Specific Tutorials and Case-Studies on Optical Microscopy and Spectroscopy Techniques. Simulations with MATLAB / Python: Signal Processing and Image Processing Tools, Hardware Interfacing, Data Acquisition and Analysis, Signal-to-Noise Ratio, Digital Image Correlation, Fourier Transform based Analysis. Experiments in Optics Laboratory: Hands-on training on Optical Alignments, building Pulse-oximeter / Hemoglobinometer, Michelson Int erferometer, and Digital Brightfield Microscope. This lab component of the course will combine the learnings from different modules of the course: Basic Concepts, Applied Theory and Computational Tools.

Sai Siva Gorthi

Pre-requistes : No Prerequisites. This is an introductory level course suitable for Students from Diverse Backgrounds: Undergrad, Int. PhD, BS-MS,

References : “Handbook of Optical Sensors” José Luís Santos , Faramarz Farahi; CRC Press; ISBN: 9781439866856 “Optical Sensors: Basics and Applications” by Jörg Haus; Wiley-VCH, ISBN: 978-3527408603 “Optical System Design” by Robert Fischer, Biljana Tadic-Galeb, and Paul Yoder; The McGraw- ill Companies, ISBN: 9780071472487 “Optical Systems Design Detection Essentials” by Robert M

IN 205 (AUG) 0 : 3

Optical Instrumentation lab 1

1. Ray Optics: Basic Ray Optics Setup, Telescope Configuration (Beam Expansion/Collimation), Measuring Intensity Profile, Data Analysis
2. Spectroscopy: Beer-Lambert Law, Design of Absorption Spectrophotometer, Fluorescence Spectrophotometer, Role Played by Scattering, Baseline Correction, Multi-point Normalisation, Sample preparation, Spectrophotometer Characterization, Calibration, Operation, Data acquisition, Analysis, and Interpretation. Students would gain hands-on experience in the design and construction of Optical Absorption Spectrophotometer and its characterization. Experimental means of measuring the spectral resolution, Sensitivity, Accuracy, and Precision. Exposes them to different means of acquiring spectral data, analysis algorithms and interpretation of spectral features, and relating them to the properties of the analyzed material.
3. Interferometry: Michelson Interferometer, To measure the wavelength of a monochromatic light source (e.g., laser), To determine the coherence length of the light source, To analyze how path difference affects interference patterns, To interpret fringe visibility and its relation to coherence.

4. Design and Simulation: Using Ansys Zeemax design of various interferometer, ray optics experiments

Sai Siva Gorthi , Jaya Prakash , Tapajyoti Das Gupta , Manukumara Manjappa

Pre-requistes : None

References : 1.Optics by Ajoy Ghatak, Mc Graw Hill, Higher education 2010
2. Basics of Interferometry (Second Edition) by P. Hariharan, Academic Press, 2007
3. Optics, Eugene Hecht, Pearson; 5th edition 2016

IN 204 (AUG) 0 : 3

Basic Instrumentation Laboratory

Analogue and Digital Electronics: Experiments on operational amplifiers, active filters, oscillators, A/D and D/A converters, phase-locked loops, mixers, lock-in amplifiers, switched mode power supplies, speed control of motors using PWM. Experiments on Control Systems, Sensors and Transducers.

Atanu Kumar Mohanty , Jayanth G R , Baladitya Suri

Pre-requistes : None

References : * Paul Horowitz and Winfield Hill, The Art of Electronics, Cambridge University Press, 2015

IN 299P (AUG) 0 : 5

Project

Third Semester Project -- The total 25 credits of the project are split into 5 credits in 3rd semester and 20 credits in the fourth semester

Baladitya Suri

Pre-requistes : None

References : NA

Mathematics

Preface

MA 219 (AUG) 3 : 1

Linear Algebra

ector spaces: definition, basis and dimension, direct sums. Linear transformations: definition, the Rank-ity Theorem, the algebra of linear transformations. Dual spaces. Matrices. Systems of linear equations: elementary theory of determinants, Cramer's rule. Eigenvalues and eigenvectors, the characteristic polynomial, the Cayley-Hamilton Theorem, the minimal polynomial, algebraic and geometric multiplicities. Diagonalization. The Jordan canonical form. Symmetry: group of motions of the plane, discrete groups of motion, finite subgroups of SO(3). Bilinear forms: symmetric, skew-symmetric and Hermitian forms, Sylvester's law of inertia, Spectral theorem for Hermitian and normal operators on finite-dimensional vector spaces.

Radhika Ganapathy

Pre-requistes : None

References : Hoffman K. and Kunze R. Linear Algebra (2nd Ed.) Prentice-Hall of India. 1992. ~Artin M. Algebra. Prentice-Hall of India. 1994.~Halmos P. Finite dimensional vector spaces. Springer-Verlag (UTM). 1987.~Lang S. Linear Algebra (3rd Ed.) Springer-Verlag (UTM). 1989.

MA 231 (AUG) 3 : 1

Topology

Point-set topology:Open and closed sets, Continuous functions, Metric topology, Product topology, Connectedness and path-connectedness, Compactness,Countability axioms, Separation axioms, Complete metric spaces, Quotient topology, Topological groups, Orbit spaces. The fundamental group: Homotopic maps, Construction of the fundamental group, Fundamental group of the circle,Homotopy type, Brouwer's fixed- point theorem, Separation of the plane.

Ved V Datar

Pre-requistes : None

References : Armstrong,M.A.,Basic Topology, Springer (India), 2004., Functional Anaysis (2nd Ed.), McGraw-Hill, 2006.~Munkres, K. R., Topology,Pearson Education, 2005, Functional Anaysis (4th Edition), Narosa, 1974.~Viro, O.Ya., Ivanov, O.A.,Netsvetaev, N., and Kharlamov, V.M., Elementary Topology: Problem Textbook,AMS, 2008.

MA 242 (AUG) 3 : 0

Partial Differential Equations

Thirupathi Gudi

Pre-requistes : None

References : Garabedian, P.R.,Partial Differential Equations, John Wiley and Sons, 1964. ~Fritz John, Partial Differential Equations, Springe (International Students Edition), 1971.~Renardy, M. and Rogers, R.C.,An Introduction to Partial Differential Equations, Springer-Verlag, 1992.~Prasad. P. and Ravindran, R.,Partial Differential Equations, Wiley Eastern, 1985.

MA 312 (AUG) 3 : 0

Commutative Algebra

Noetherian rings and Modules, Localisations, Exact Sequences, Hom, Tensor Products, Hilbert's -stellensatz, Integral dependence, Going-up and Going down theorems, Noether's normalization lemma , Discrete valuation rings and Dedekind domains.

Bharathwaj Palvannan

Pre-requistes : None

References : None

MA 313 (AUG) 3 : 0

Algebraic Number Theory

Number fields and rings of integers, Dedekind domains; prime factorization, ideal class group, finiteness of class number, Dirichlet 's unit theorem, cyclotomic fields, theory of valuations, local fields.

Bharathwaj Palvannan

Pre-requistes : None

References : Jurgen Neukirch, Algebraic Number theory, Springer, 1999~Daniel A. Marcus,Number fields, Springer Universitext, 2018~J.P Serre, Local fields, Springer GTM 67, 1979

MA 361 (AUG) 3 : 0

Probability theory

Discrete parameter martingales: Conditional expectation. Optional sampling theorems. Doob's inequalities. Martingale convergence theorems. Applications.Brownian motion. Construction. Continuity properties. Markov and strong Markov property and applications. Donsker's invariance principle. Further sample path properties.Ergodic theory (if time permits) Probability measures and random variables, pi and lambda systems, expectation,the moment generating function, the characteristic function,laws of large numbers, limit theorems, conditional contribution and expectation, martingales, infinitely divisible laws and stable laws.

Manjunath Krishnapur

Pre-requistes : None

References : Rick Durrett, Probability:theory and examples., Cambridge University Press,2010~David Williams, Probability with Martingales, Cambridge Univ., Press,1991~Peter Mörters and Yuval Peres, Brownian motion, Cambridge University Press, 2010~Olav Kallenberg, Foundations of modern Probability. Second Edition, Springer-Verlag, 2002~John Walsh, Knowing the Odds: An Introduction to

MA 200 (AUG) 3 : 1

Multivariable Calculus

Functions on R^n, directional derivatives, total derivative, higher order derivatives and Taylor series.The inverse and implicit function theorem, Integration on R^n, differential forms on R^n, closed and exact forms.Green’s theorem, Stokes’ theorem and the Divergence theorem.

Vamsi Pritham Pingali

Pre-requistes : None

References : Rudin, Principles of Mathematical Analysis, McGraw-Hill, 1986.~B. V. Limaye and S. Ghorpade, A course in Calculus and Real Analysis, Springer~Spivak, M.,Calculus on Manifolds, W.A. Benjamin, co., 1965

MA 389A (AUG) 1 : 0

Seminar on topics in mathematics I

The students must commit to attending a seminar series (algebra, eigenfunctions, etc) of their choice and attend all the talks during the semester.

Vamsi Pritham Pingali

Pre-requistes : None

References : No references.

MA 347B (AUG) 3 : 0

Hyperbolic Conservation Laws: Theory, Numerics, and Applications

This course illustrates the interplay between mathematical theory and numerical analysis leading to an understanding of some of the famous real-world problems modeled by hyperbolic conservation laws. Main topics include:
1. Linear Transport Equation: Method of characteristics; classical solutions; finite difference methods and their convergence analysis (Lax equivalence theorem).
2. Scalar Conservation Laws: Method of characteristics; weak solutions; Rankine-Hugoniot condition; Riemann problems; mathematical entropy; initial value problems (IVPs); initial boundary value problems (IBVPs); Kruzkov's uniqueness theorem.
3. L^1 space and BV Compactness: Helly's Theorem.
4. Numerical Methods and Existence Results for IVPs:
a. Front Tracking Method: BV bounds and convergence analysis.
b. Finite Volume Method: Monotone schemes; BV bounds and convergence analysis (Lax-Wendroff theorem).
c. Splitting Method: Source splitting; dimension splitting; BV bounds and convergence analysis.
5. Applications and Numerical Simulations: Traffic models (LWR models); two-phase flow in porous media (Buckley-Leverett model).
6. System of Conservation Laws: Hyperbolicity, weak and entropy solutions; Lax-Liu entropy condition; Riemann problems; uniqueness results (statements only)
7. Applications and Numerical Simulations: Dam-breaking problem (shallow water equations); chromatography equation; Euler equations.

Ganesh Kiran Vaidya

Pre-requistes :
Topics from MA222 and MA242 are desirable but not absolutely

References : 1. A. Bressan, Hyperbolic systems of conservation laws: the one-dimensional Cauchy problem, Oxford Lecture Ser. Math. Appl., Oxford University Press, Oxford, 2000.
2. E. Godlewski and P.-A. Raviart, Hyperbolic systems of conservation laws [No. 3-4], Ellipses, Paris, 1991.

Physics

Preface

HE 215 (AUG) 3 : 0

Nuclear and Particle Physics

Radioactive decay, subnuclear particles. Binding energies. Nuclear forces,pion exchange, Yukawa potential. Isospin, neutron and prot on.Deuteron. Shell model, magic numbers. Nuclear transitions,selection rules. Liquid drop model,collective excitations. Nuclear fission and fusion. Beta decay. Neutrinos.Fermi theory, parity violation, V-A theory. Mesons and baryons. Lifetimes and decay processes. Discrete symmetries, C, P, T and G. Weak interaction transition rules.Strangeness, K mesons and hyperons. Hadron multiplets,composition of mesons and baryons. Quark model and quantum chromodynamics.

Sudhir Kumar Vempati

Pre-requistes : None

References : Povh B.,Rith K.,Scholz C. and Zetsche F., Particles and Nuclei: An Introduction to Physical Concepts (Second edition), Springer, 1999~Krane K.S.,Introductory Nuclear Physics, John Wiley & Sons, 1988~Griffiths D., Introduction to Elementary Particles, John Wiley & Sons, 1987~Perkins D.H.,Introduction to High Energy Physics (Third edition), Addison Wesley, 1987~

PH 201 (AUG) 3 : 0

Classical Mechanics

Newton's laws, generalized co-ordinates. Lagrange's principle of least action and equations. Conservation laws and symmetry. Integrable problems, elastic collisions and scattering. Small oscillations including systems with many degrees of freedom, rigid body motion. Hamilton's equations. Poisson brackets. Hamilton Jacobi theory. Canonical perturbation theory, chaos, elements of special relativity. Lorentz transformations, relativistic mechanics.

Baladitya Suri

Pre-requistes : None

References :

PH 203 (AUG) 3 : 0

Quantum Mechanics-I

Historical foundations. Wave function for a single particle. Hamiltonian. Schrodinger equation. Probability current. Wave packets. One-dimensional problems: step, barrier and delta-function potentials. Tunnelling, scattering and bound states. Harmonic oscillator, operator approach. Matrix formulation of quantum mechanics. Hermitian and unitary operators. Orthonormal basis. Momentum representation. Uncertainty relations. Postulates of quantum mechanics. Heisenberg representation. Ehrenfest's theorem. Three dimensional problems. Rotations, angular momentum operators, commutation relations. Spherical harmonics. Hydrogen atom, its spectrum and wave functions. Symmetries and degeneracies. Spin angular momentum. Spin-1/2 and two-level systems. Addition of angular momentum. Spin-orbit and hyperfine interactions. Time-independent perturbation theory. Stark and Zeeman effects. Variational methods, ground state of helium atom.

Banibrata Mukhopadhyay

Pre-requistes : None

References : None

PH 205 (AUG) 3 : 0

Math Methods of Physics

Justin Raj David

Pre-requistes : None

References : Linear vector spaces, linear operators and matrices, systems of linear equations. Eigen values and eigen vectors, classical orthogonal polynomials. Linear ordinary differential equations, exact and series methods of solution, special functions. Linear partial differential equations of physics, separation of variables method of solution. Complex variable theory; analytic functions. Taylor and Laurent

PH 207 (AUG) 1 : 2

Electronics I

Basic diode and transistor circuits, operational amplifier and applications,active filters, voltage regulators, oscillators, digital electronics, logic gates, Boolean algebra, flip-flops, multiplexers, counters, displays, decoders, D/A, A/D. Introduction to microprocessors.

Shubhadeep Biswas

Pre-requistes : None

References : Horowitz and Hill, The Art of Electronics, Second Edn.,Millman and Halkias, Integrated Electronics, McGraw Hill.,Horowitz and Hill, The Art of Electronics, Second Edn.

PH 211 (AUG) 0 : 3

General Physics Laboratory

Diffraction of light by high frequency sound waves, Michelson interferometer, Hall effect, band gap of semiconductors, diode as a temperature sensor, thermal conductivity of a gas using Pirani gauge, normal modes of vibration in a box, Newton’s laws of cooling, dielectric constant measurements of triglycine selenate, random walk in porous medium.

Aveek Bid , Srimanta Middey

Pre-requistes : None

References : None

PH 213 (AUG) 0 : 4

Advanced Experiments in Condensed Matter Physics

Sputtering, PLD, MBE, XRD, XRR, XPS, VSM, Resistivity, DSC, TGA/DTA, etc.

Anil Kumar P S

Pre-requistes : None

References : None

PH 217 (AUG) 3 : 0

Fundamentals of Astrophysics

Overview of the major contents of the universe. Basics of radiative transfer and radiative processes. Stellar interiors. HR diagram. Nuclear energy generation. White dwarfs and neutron stars. Shape, size and contents of our galaxy. Basics of stellar dynamics. Normal and active galaxies. High energy and plasma processes. Newtonian cosmology. Microwave background. Early universe.

Ashish Kumar Meena

Pre-requistes : None

References : None

PH 300 (AUG) 1 : 0

Seminar Course

Nirupam Roy

Pre-requistes : None

References : None

PH 320 (AUG) 3 : 0

Condensed Matter Physics - II

Review of one-electron band theory. Effects of electron-electron interaction: Hartree – Fock approximation, exchange and correlation effects, density functional theory, Fermi liquid theory, elementary excitations, quasiparticles. Dielectric function of electron systems, screening, plasma oscillation. Optical properties of metals and insulators, excitons. The Hubbard model, spin-and charge-density wave states, metal-insulator transition. Review of harmonic theory of lattice vibrations. Anharmonic effects. Electron-phonon interaction – phonons in metals, mass renormalization, effective interaction between electrons, polarons. Transport phenomena, Boltzmann equation, electrical and thermal conductivities, thermo-electric effects. Superconductivity–phenomenology, Cooper instability, BCS theory, Ginzburg-Landau theory

Sumilan Banerjee

Pre-requistes : None

References : None

PH 325 (AUG) 3 : 0

Advanced Statistical Physics

Systems and phenomena. Equilibrium and non-equilibrium models. Techniques for equilibrium statistical mechanics with examples, exact solution, mean field theory, perturbation expansion, Ginzburg Landau theory, scaling, numerical methods. Critical phenomena, classical and quantum. Disordered systems including percolation and spin glasses. A brief survey of non-equilibrium phenomena including transport, hydrodynamics and non-equilibrium steady states.

Vijay B Shenoy

Pre-requistes : None

References : None

PH 353 (AUG) 3 : 0

Principles of Magnetism

Srimanta Middey

Pre-requistes : None

References : None

PH 378 (AUG) 3 : 0

Discrete Photonics and Quantum Analogies

Introduction, Maxwell's equation; Guided wave structures, scalar-paraxial approximation, analogy with Schrödinger equation; Photon statistics, classical and non-classical light; Waveguide modes; Evanescent coupling, coupled two-level system, coupled mode (tight binding) theory; Periodic structures: one-dimensional and two-dimensional, discrete diffraction, photonic band theory, gratings, optical Bloch oscillations; Periodically modulated structures: Floquet theory, effective Hamiltonian, quasi-energy spectrum; Optical pulse propagation, Kerr effect, nonlinear Schrödinger equation, self-phase modulation, solitons; Methods of creating waveguides; Recent development

Sebabrata Mukherjee

Pre-requistes :
Basic understanding of electromagnetic theory, quantum mechanics and solids

References : 1. A W Snyder and J Love, "Optical Waveguide Theory," Springer Science & Business Media
2. A Ghatak and K Thyagarajan, "Introduction to Fibre Optics," Cambridge University Press
3. D J Griffiths, “Introduction to Quantum Mechanics,” Pearson Prentice Hall

PH 373 (AUG) 3 : 0

Introduction to Fluid Mechanics and Plasma Physics

Boltzmann equation. Derivation of fluid equations. An introduction to stellar dynamics. Important properties of ideal and viscous fluid flows. Gas dynamics. Waves in fluids. Hydrodynamics stability. Turbulence. Plasma orbit theory.Debye shielding and collective behaviour. Waves and oscillations inplasmas.From the Vlasov equation to MHD equations. Flux freezing. MHD waves. Reconnection andrelaxation. Dynamo theory.

Prantika Bhowmik

Pre-requistes :

None

References : [1] Acheson: Elementary Fluid Dynamics [2] R. Blandford & K. Thorne: Application of Classical Physics [3] F. F. Chen: Introduction to Plasma Physics and Controlled Fusion [4] A. Rai Choudhuri: The Physics of Fluids and Plasmas [5] P. G. Drain & W. H. Reid: Hydrodynamic stability [6] R. Kulsrud: Plasma Physics for Astrophysics [7] Landau & Lifshitz: Fluid Mechanics

PH 372 (AUG) 3 : 0

Radiative Processess in Astrophysics

Elements of radiative transfer and stellar atmospheres. Theory of grey atmospheres. Covariant formulation of classical electrodynamics. Radiation from accelerated charges. Cyclotron and synchrotron radiation. Bremsstrahlung. Thomson and Compton scattering. Plasma effects. Atomic and molecular spectra.Transition rates and selection rules. Opacity calculations. Line formation in stellar atmospheres.

Prantika Bhowmik

Pre-requistes :

References : G. Rybicki & A. Lightman: Radiative Processes in Astrophysics

PH 393 (AUG) 3 : 0

Next Generation Strategies for Engineering and Pro

Thermodynamics of growth (nucleation, mechanisms of growth, phase diagrams), Concepts of epitaxy and related energetics, nucleation and growth mechanisms. Thin film characterization, concepts of ultra high vacuum, deposition techniques such as sputtering, evaporation, LPE,MOCVD, MBE, PLD, CVD, PECVD, MOCVD and Electro-deposition, Measurement and characterization such as RHEED, LEED, thin-film XRD, optical techniques. Case studies including 2D material growth, Finite Element Modelling, AI-ML enabled synthesis optimization.

Anil Kumar P S , Akshay Singh

Pre-requistes :

none

References : 1) Material Science of Thin Films (Milton Ohring)
2) Thin Film Phenomena (KL Chopra)

Instrumentation and Applied Physics_QT

Preface

QT 207 (AUG) 3 : 0

Introduction to Quantum Computation

Axiomatic quantum theory; Quantum states, observables, measurement and evolution; Qubits versus classical bits; Spin-half systems and photon polarizations; Pure and mixed states; Density matrices; Quantum correlations; Entanglement and Bell's theorems; Turing machines and computational complexity; Reversible computation; Universal quantum logic gates and circuits; Quantum algorithms; Database search; Fast Fourier Transform and prime factorisation.

Chandrashekar C M

Pre-requistes : None

References : Nielsen M.A. and Chuang I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2000.Peres A., Quantum Theory: Concepts and Methods, Kluwer Academic, 1993. Preskill J., Lecture Notes for the Course on Quantum Computation, http://www.theory.c altech.edu/people/preskill/ph229

QT 209 (AUG) 3 : 0

Introduction to Quantum Communications and Cryptography

Digital communication; Communication channels; Information and entropy; Shannon's theorems; Quantum communication, dense coding and teleportation; von Neumann entropy and quantum channel capacity; General quantum evolution and superoperators; Errors and error correction codes; Stabilizer formalism; Cryptography and one-time pad; Public and private key cryptography; Quantum key distribution; Quantum cryptography. Geometrical and wave optics; Quantisation of the electromagnetic field; Photon number states; Coherent states; Squeezing and beam-splitters.

Sanjit Chatterjee , Varun Raghunathan , Manukumara Manjappa

Pre-requistes : None

References : Nielsen M.A. and Chuang I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2000. Preskill J., Lecture No tes for the Course on Quantum Computation, http://www.theory.caltech.edu/people/preskill/ph229

QT 211 (AUG) 1 : 2

Basic Quantum Technology Laboratory

Intro to RF equipment – VNA, signal generators, AWGs,Oscilloscopes, Basics of Microwave Engineering – Impedance,S-parameters, Charac terisation of passive RF components – Cables, terminations,attenuators, directional couplers, RF mixer, filters, circulators and isolators, Python packages from Quantum Optics and Quantum computation – QISKIT and QuTiP, Simulating basic quantum Hamiltonians,Dissipative systems, Quantum circuit simulations.

Vibhor Singh

Pre-requistes : None

References : 1. David Pozar, Microwave Engineering 2. QISKIT and QuTiP programming manual

QT 202 (AUG) 3 : 0

Introduction to Quantum Measurement

Introduction to Classical Measurement, Introduction to quantum mechanics through measurement, the quantum measurement postulate and its consequences, standard quantum limits (SQL), types of measurements – direct and indirect measurements, orthogonal, non-orthogonal, quantum non-demolition measurements, linear measurements and amplification, beyond the SQL - parametric amplification. Case studies of measurement – quantized charge measurement, single photon detection, non-demolition method for photon quadrature measurements etc. Control of single quantum systems, introduction to decoherence – decoherence as measurement by environment, characterizing decoherence in qubits, openloop control and stabilization of qubit states.

Baladitya Suri

Pre-requistes :

References : Quantum Measurement by Braginsky and Khalili Quantum measurement by Wiseman and Milburn Mechanics by Landau-Lifshitz.

Mathematical Science_Int PhD

Preface

Physical Sciences

Preface